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U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES
1937

By ELMER HIGGINS

ADMINISTRATIVE REPORT No. 30

U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary

BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

Administrative Report No. 30

PROGRESS IN BIOLOGICAL INQUIRIES
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APPENDIX I TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1938

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ADMINISTRATIVE REPORT SERIES

Since the beginning of the Administrative Report Series, considerable confusion has arisen concerning the system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations as "Appendix No. I, II, III, or IV" very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates had already been printed in this series before starting the numbers, it was deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 25 were, they are numbered for filing purposes as follows:

No. 1. Report, Commissioner of Fisheries, 1931.
No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
No. 3. Fishery Industries of the United States, 1930.
No. 4. Progress in Biological Inquiries, 1930.
No. 5. Propagation and Distribution of Food Fishes, 1931.
No. 6. Report, Commissioner of Fisheries, 1932.
No. 7. Alaska Fishery and Fur-Seal Industries, 1931.
No. 8. Fishery Industries of the United States, 1931.
No. 9. Progress in Biological Inquiries, 1931.
No. 10. Propagation and Distribution of Food Fishes, 1932.
No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
No. 12. Progress in Biological Inquiries, 1932.
No. 13. Fishery Industries of the United States, 1932.
No. 14. Propagation and Distribution of Food Fishes, 1933.
No. 15. Fishery Industries of the United States, 1933.
No. 16. Alaska Fishery and Fur-Seal Inquiries, 1933.
No. 17. Progress in Biological Inquiries, 1933.
No. 18. Propagation and Distribution of Food Fishes, 1934.
No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
No. 20. Fishery Industries of the United States, 1934.
No. 21. Progress in Biological Inquiries, 1934.
No. 22. Propagation and Distribution of Food Fishes, 1935.
No. 23. Alaska Fishery and Fur-Seal Industries, 1935.
No. 24. Fishery Industries of the United States, 1935.
No. 25. Propagation and Distribution of Food Fishes, 1936.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1937 [1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

CONTENTS

Page
Introduction 1
Cooperation 5
Publications 6
North Atlantic fishery investigations 8
    Haddock 9
    Mackerel 14
Middle and South Atlantic fishery investigations 16
    Shore fishes 18
    Anadromous fishes 20
Shrimp investigations 23
North Pacific and Alaska fishery investigations 25
    Columbia River salmon fisheries 26
    Puget Sound salmon fisheries 28
    Karluk River red salmon 31
    Pink salmon 33
    Alaska salmon statistics 35
    Herring 35
Pacific pilchard investigations 37
Great Lakes fishery investigations 38
    Fishery statistics 39
    Age and growth studies 40
    Food of Lake Michigan lake trout and lawyers 40
    Special surveys 41
Shellfish investigations 42
    Physiology of the oyster 43
    Oyster cultural studies 44
    Special surveys 50
Aquicultural investigations 52
    Trout 53
    Bass 60
    Fish diseases 63
Investigations in interior waters 64
    Pollution studies 64
    Mussel propagation 66
Ichthyological investigations 66
Independent activities of the fisheries biological laboratories 67
    Woods Hole, Mass 67
    Beaufort, N. C 67
Appropriations 70

INTRODUCTION

To an ever-increasing degree, efforts in the field of fishery science are bringing the resources of the waters under a measure of human control. Particularly is this true of the important shellfish supplies of the Atlantic, Gulf, and Pacific coasts and of the stocks of game and commercial fishes in the interior waters. Principles of fish management developed by scientific research have been applied with conspicuous success to these fisheries. The application of similar management practices to the great marine fisheries is relatively a virgin field, but one in which encouraging progress is being made.

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[1] Administrative Report No. 30, Appendix I to Report of the U. S. Commissioner of Fisheries for 1938 Approved for publication June 4, 1938.

As a basis for effective fish husbandry, direct and continuing observations of the fisheries themselves are essential. In addition, fundamental problems of fishery conservation are often solved only with the aid of highly technical laboratory research. Both types of studies are necessarily carried on over long periods of time, and progress reported in any particular year must be interpreted in relation to the whole program of investigations of which it forms a part. Nevertheless outstanding trends and developments in the commercial fisheries during the year 1937, as well as important achievements in the biological investigations conducted by the Division of Scientific Inquiry, may well be summarized at this time.

Commercial Fisheries.—In the North Atlantic area notable developments occurred in both the mackerel and haddock fisheries. The spectacular decline of the mackerel catch to a level which was only about one-third of the previous year's yield was an event of economic and biological consequence, resulting in a sharp increase in price per pound, but in a greatly reduced total return. This decline, of unforeseen magnitude, is believed to be the result of oceanographic conditions at present not understood, which prevented the mackerel from congregating in the usual fishing areas. The year continued the downward trend in haddock landings begun in 1931. Of even greater significance is the fact that it was the first year of simultaneous decline in abundance (as measured in terms of catch per trawler per day) on the Georges and Nova Scotian banks. Declining abundance on Georges Bank drove the greater part of the otter trawl fleet to the distant Nova Scotian banks in 1934, giving the former area an opportunity for moderate recovery. By 1936, however, the catch per day on the Nova Scotian banks began to decline and a return to Georges Bank followed, again increasing the strain on the inshore banks. As a result of these shifts, both major haddock areas are now in a state of declining abundance. The developments in these two fisheries emphasize the need for continuation and extension of the biological studies that have been prosecuted by the Division in this area. It is the purpose of these studies to provide knowledge of the limits of safe exploitation by the haddock fishery and to establish a sound basis for prediction of fluctuations in mackerel abundance.

A program of studies designed to direct the rehabilitation of the seriously depleted shad fishery was initiated during the year in the Middle and South Atlantic area. Headquarters for the fishery investigations of this entire section have been transferred from Massachusetts to a more centralized location at College Park, Md., and a field laboratory has been established at Charleston, S. C. A survey of Long Island fisheries by the Bureau staff in cooperation with the New York Conservation Department has been launched to provide information on the relative intensity of the commercial and the growing sports fisheries of this region. A flounder tagging program carried out by the Bureau in cooperation with the State of Rhode Island has already demonstrated that the catch by sportsmen in many cases forms a significant proportion of the total poundage taken. Continued studies of scup, squeteague, and other fishes which migrate widely along the Atlantic coast, as well as of such anadromous species as shad and striped bass, are expected to provide basic knowledge for the application of fishery management practices which are critically needed in this area.

In the shrimp fishery of the South Atlantic coast the picture is one of continued increase in number of boats and amount of gear fished and of a catch which fails to increase in spite of augmented fishing effort. Fishing operations are consequently growing less profitable and the need of better protection for the young shrimp is clearly indicated. The tagging program, continued through 1937, gave additional information on the coastwise movements of shrimp and demonstrated that protection of the supply is an interstate problem. Investigations on both South Atlantic and Gulf coasts were pursued jointly with the conservation departments of several southern states for the purpose of devising a system of rational management for the fishery.

To provide a continuous fund of information for their proper regulation, studies of the salmon fisheries of Alaska were continued without interruption or material change. In the Karluk area, where effort is being concentrated on the causes of fresh water mortality among young red salmon, marked progress was made in studies of predatory species. Further light on the factors which affect the returns from escapements of pink salmon was gained, and tagging experiments on sockeye, coho, and chinook salmon were continued in the Puget Sound area and on the Columbia River. Progress may also be reported on the investigation of the entire Columbia River Basin to determine what protective and restorative measures are necessary for the protection of the salmon runs of that river. Approximately 2,300 miles of stream have now been surveyed in the Columbia watershed for the purpose of discovering additional spawning grounds that may be restored for use by salmon and of locating obstructions to migrating fish and hazards to downstream migrants in the form of unscreened irrigation ditches.

During the latter part of the year headquarters were established in California for the investigation of the pilchard fishery. Greatly increased exploitation of the Pacific sardine or pilchard within recent years has given rise to fears for the safety of the resource. The investigation is planned to determine whether overfishing exists and to prescribe proper measures for regulation of the fishery, should regulation be found necessary.

Important advances in State administration of the fisheries have been made during the year in the Great Lakes area with the adoption of the flexible rule method of measuring gill net meshes by Wisconsin, Illinois, Michigan, and Ohio, and the passage of a discretionary power act by the Wisconsin legislature, giving wider legislative powers to State conservation officials. Continuing its cooperation with State officials and the fishing industry, the Great Lakes staff has acted in a fact-finding and advisory capacity in several important conservation problems during the year. Life history studies of important commercial species have been continued and statistical analyses of commercial fishing records have provided additional evidence of the severe depletion existing in the Great Lakes fisheries.

Shellfisheries.—Oyster investigations during the year added to the physiological and ecological knowledge on which successful oyster culture is based. In the New England section there was inaugurated the important service of predicting the time and relative intensity of spawning and setting, thus enabling growers to plant their shells at the proper time to obtain the maximum set of larval oysters. Studies on the starfish demonstrated clearly that the control of this destructive enemy of the oyster is an interstate problem and that more effective and better coordinated measures must be taken for its eradication. Experiments looking toward chemical control of starfish have progressed to such a point that their practical application during 1938 seems assured. Additional evidence has been secured of the detrimental effect of pulp-mill effluent on shellfish. Studies of the precise nature and physiological effect of the effluent will be of great assistance in any efforts that may be made to remedy this pollution hazard. Ecological surveys made by the staff in Long Island Sound, Virginia, North Carolina, Alabama, and Florida have been used by State conservation authorities for the protection and improvement of shellfish resources of the coast. During the year a new laboratory was established at Pensacola, Fla., to serve as headquarters for oyster investigations of the Gulf area.

Fresh water fisheries.—In recognition of the critical need for a broader basis of scientific fact to direct the rapidly expanding fish cultural operations throughout the country, investigations of the aquicultural staff have been directed in particular toward the development of new and more effective methods, both in the rearing and stocking of fish. The continued operation of test streams in Vermont has demonstrated the value of this procedure as a yardstick for measuring the success of stocking in trout waters. The Pisgah National Forest in which an experimental project has now been under way for more than a year provides an excellent natural laboratory for the application and testing of fish management practices. Here studies are under way to determine the size of fish and the intensity of stocking which produce most satisfactory results and to test the effect of various types of stream improvement on the production of fish and food organisms. Through the operation of experimental streams in California, data are being collected on the survival rates of hatchery trout planted at various ages and under varying predator conditions. The accumulation of such information over a period of years will serve as a definite guide for stocking programs.

In the fundamental nutrition studies which have been continued at Cortland, N. Y., current hatchery feeding practices are being improved through the testing of a great variety of products. Through biochemical and physiological studies, an attack has been made on the important problem of so adjusting the growth rate of hatchery fish that the most desirable physical development will be produced.

Because fish management practices as applied to bass have received little attention from fish culturists in general, fundamental problems in this field remain unsolved. Determination of the effectiveness of natural propagation, which in the case of bass may prove to be more efficient than artificial propagation, is obviously a first consideration. Observations on the time of spawning, the production of fry, and the food and growth of the young bass have therefore been conducted during the year in selected waters. Continuation of these studies gives promise of yielding results of great practical importance by indicating whether the efforts of fish culturists may more profitably be spent on artificial propagation or on the improvement of natural conditions in bass waters.

At the Quilcene, Wash., hatchery, both preventive and therapeutic measures for combating common hatchery diseases were investigated under controlled conditions. The superiority of this experimental approach to the problem of hatchery disease has already been clearly demonstrated during the comparatively short time the laboratory has been in operation.

Every State and every major river system have now been included in the stream pollution studies conducted from headquarters at Columbia, Mo. Data so gathered have been applied to the solution of numerous fisheries problems, and applications of these findings are being made by manufacturers for the correction of pollution hazards with increasing and encouraging frequency. Physiological experiments to determine the cumulative effect of substances naturally present in many waters in minute quantities have yielded results of great significance. In cooperation with the National Research Council, investigations of the fisheries problems in several of the larger impoundments of water in the western part of the country have been initiated. Results of these studies, as yet incomplete, are already finding practical application in connection with stocking programs.

COOPERATION

As in previous years, the Bureau again gratefully acknowledges extensive cooperation in the conduct of biological investigations of the fisheries which, during the past year, has extended and rounded out materially the program of work. This cooperation includes active participation in research projects by the personnel of the Bureau of Fisheries and other agencies, the furnishing of laboratory and office quarters, equipment, boats, personnel, and other facilities and services, and, in some cases, the donation of funds to joint projects. Such cooperation has been afforded by universities, research institutions, agencies of the State governments, such as fish and game commissions and surveys, and various Federal agencies concerned with the management of natural resources with collateral interests in fisheries.

Several of the sections of the Division of Scientific Inquiry are afforded headquarters for their regional activities by the universities where laboratory and library facilities are unexcelled. Cooperation from the States has consisted generally in the furnishing of office and laboratory headquarters, the provision of boats and assisting personnel, and in some cases the active participation in investigative programs with a joint staff of Federal and State employees. In one instance a brief investigation was undertaken entirely on funds provided by a commercial fishery organization.

Cooperation with Federal agencies has shown continued improvement during the past year. A cooperative program with the Forest Service is continuing upon a mutually satisfactory basis and similar cooperation has been effected with the Tennessee Valley Authority.

The Reclamation Service with the assistance of the Bureau is undertaking increased activities in protecting fisheries from irrigation projects. The Federal Power Commission is supporting the Bureau's efforts to provide suitable fish protection on all projects constructed under license from that agency in accordance with law. The Bureau has been able also to extend its cooperation with the Indian Service in the development and protection of the fishery resources on reservations. Through the work of the National Resources Committee and the Council of State Governments, both of which agencies have called upon the Bureau for assistance, additional attention is being given to the development of coordinated programs of fishery conservation throughout the country demonstrating again the opportunities for effectively integrating all of the activities of government at various levels in this field.

Specific acknowledgment of cooperation afforded by the various agencies is generally included in each of the succeeding sections of this report.

PUBLICATIONS

Owing to the curtailment of funds for printing, the number of publications resulting from investigations of the staff has been reduced. The list of papers published by the Bureau during 1937 follows:

Galtsoff, Paul S., H. F. Prytherch and J. B. Engle.
Natural history and methods of controlling the common oyster drills (*Urosalpinx cinerea* Say and *Eupleura caudata* Say). Fishery Circular No. 25, 24 pp., 13 figs.

Higgins, Elmer.
Progress in Biological Inquiries, 1936. Administrative Report No. 29, 61 pp.

Hilderbrand, Samuel F., and Louella E. Cable.
Further notes on the development and life history of some teleosts at Beaufort, N. C. Bulletin No. 24, 137 pp., 159 figs.

Hopkins, A. E.
Experimental observations on spawning, larval development, and setting in the Olympia oyster, *Ostrea lurida*. Bulletin No. 23, 64 pp., 41 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry during the year 1937, outside of the Bureau of Fisheries series:

Davidson, Frederick A.
Migration and homing of Pacific salmon. Science, vol. 86, No. 2220, pp. 55–56.

Ellis, M. M.
Pollution and aquatic life. Proceedings, Second North American Wildlife Conference, pp. 653–658.

Ellis, M. M., H. L. Motley, M. D. Ellis, and R. O. Jones.
Selenium poisoning in fish. Proceedings of the Society for Experimental Biology and Medicine, vol. 36, pp. 519–522.

Ellis, M. M., H. L. Motley, and M. D. Ellis.
Sore throats from exposure to selenium. Journal, American Medical Association, vol. 109, pp. 1717–1718.

Firth, Frank E.
Recent records extending the range of *Caulolatilus microps* north of Florida. Copeia, No. 3 (1937), p. 189.

Firth, Frank E., and E. W. Gudger.
Two reversed partially ambicolorate halibuts: *Hippoglossus hippoglossus*. American Museum Novitates, No. 925.

GALTSOFF, PAUL S.

General methods of collecting, maintaining, and rearing marine invertebrates in the laboratory. Culture Methods for Invertebrate Animals. Comstock Publishing Co., pp. 3–36.

Hatching and rearing larvae of the American lobster. Ibid., pp. 233–236.

Spawning and fertilization of the oyster, *Ostrea virginica.* Ibid., pp. 537–538.

Observations and experiments on sex change in the adult American oyster, *Ostrea virginica.* Collecting Net, vol. 12, No. 8, pp. 187–188; and Biological Bulletin, vol. LXXIII, p. 356.

A story of the first zoologist in Alaska. Review of Dr. Leonhard Stejneger's book, "Georg Wilhelm Steller." Collecting Net, vol. 12, pp. 64–65.

GALTSOFF, PAUL S., H. F. PRYTHERCH, and J. B. ENGLE.

Controlling the common oyster drill. Western Fisheries, vol. 15, pp. 12–15.

GINSBURG, ISAAC.

Review of the seahorses (Hippocampus) found on the coasts of the American continents and of Europe. Proceedings, U. S. National Museum, vol. 83, pp. 497–594.

The species and its subdivision. Copeia, No. 3 (1937), pp. 184–188.

HILDEBRAND, SAMUEL F.

The tarpon in the Panama Canal. Scientific Monthly, vol. 44, March, pp. 239–248, 4 figs.

HILE, RALPH.

Morphometry of the cisco, *Leucichthys artedi* (Le Sueur), in the lakes of the Northeastern Highlands, Wisconsin. Internationale Revue der gesamten Hydrobiologie und Hydrographie, Band 36, Heft ½, s. 57–130.

KELEZ, GEORGE B.

Hook and line catches in Puget Sound. Fishing Directory of Western Washington, E. Bauer, Seattle, Wash.

LOOSANOFF, V. L.

Development of the primary gonad and sexual phases in *Venus mercenaria* Linnaeus. Biological Bulletin, LXXII, June, pp. 389–405.

Oyster pest control studies in Long Island Sound. State of Conn. Biennial Report of Shellfish Commissioners, 1935–36. Doc. No. 30: pp. 10–14.

Seasonal gonadal changes of adult clams, *Venus mercenaria.* Biological Bulletin, LXXII, June, pp. 406–416.

Spawning of *Venus mercenaria.* Ecology, vol. 18, No. 4. October, 506–515.

The spawning run of the Pacific surf smelt, *Hypomesus pretiosus* (Girard). International Revue der gesamten Hydrobiologie und Hydrographie, Band 36, S. 170–183. Akademische Verlagsgesellschaft m. b. H., Leipzig.

Spermatogenesis in the hard shell clam, *Venus mercenaria* Linnaeus. Yale Journal of Biology and Medicine, vol. 9; May, pp. 437–442.

Use of Nile Blue Sulphate in marking starfish, Science, vol. 85, No. 2208, p. 412.

MEEHEAN, LLOYD.

Additional notes on *Argulus trilineatus* (Wilson). Ohio Journal of Science, vol. 37, No. 5, pp. 288–292.

The relative importance of plankton constituents in bass ponds as measured by the organic content. International Revue der gesamtem Hydrobiologie und Hydrographie, Band 36, S. 131–137.

NEEDHAM, P. R.

Methods of measuring anglers' catches in inland waters. Copeia, No. 1 (1937), pp. 41–48.

Notes on the introduction of *Salmo nelsoni* Evermann into California from Mexico. Transactions of the American Fisheries Society, vol. 67. In press.

NESBIT, ROBERT A.

Some results of trout tagging in Massachusetts. Copeia, No. 3 (1937), pp. 168–172.

VAN OOSTEN, JOHN.

First records of the smelt, *Osmerus mordax,* in Lake Erie. Copeia, No. 1 (1937), pp. 64–65.

Doom of the Great Lakes fisheries. American Forests, vol. 43, No. 3, pp. 103–105, 144–145.

The artificial propagation of the commercial species of fish of the Great Lakes. Proceedings, Second North American Wildlife Conference, pp. 605–612.

MISCELLANEOUS PUBLICATIONS

The following publications were issued by the Division of Scientific Inquiry or prepared with its cooperation:

U. S. Bureau of Fisheries.
  The Progressive Fish Culturist. Memorandum I-131, 9 issues.
  Fishes of the Great Lakes. Memorandum I-134D.
  Migratory fish of the Atlantic and Gulf coasts. Special memorandum No. 3239. (With Division of Fishery Industries.)
Senate Document No. 87.
  Bonneville Dam and the protection of the Columbia River fisheries. A report of the Commissioner of Fisheries transmitting, in response to Senate Resolution No. 113, a survey of the facilities for the passage of salmon at Bonneville on the Columbia River with recommendations for the conservation and the preservation of the fishing industry. July 22, 79 pp.

Progress reports of the investigations conducted by the various sections, prepared in the main by the section heads, are given in the following pages.

NORTH ATLANTIC FISHERY INVESTIGATIONS

William C. Herrington, *in charge*

In many respects 1937 was a disappointing year in the New England vessel fisheries. After a steady increase since 1932 in both quantity and value of catch, 1937 witnessed a decline of 6 percent in catch and 12 percent in value below the previous year. The decline in catch is particularly noteworthy, occurring as it did in spite of the increase in size of the fishing fleet through the addition of 10 large otter trawlers and several smaller vessels. The decrease in value per pound also is worthy of comment in view of the fact that meat prices during the same period were at their highest in many years.

Although the catch of several species, notably cod and flounders, increased, this gain was more than counterbalanced by declines in the catch of mackerel, whiting, redfish (rosefish), haddock, and pollock. The decrease in whiting and redfish possibly was a reaction from the meteoric expansion of these fisheries during the previous year, but the drop in mackerel and haddock was due to other than economic causes.

The most outstanding event both economically and biologically was the relative failure of the mackerel fishery. The 1937 catch reached but 14 or 15 million pounds, a decline of about 65 percent below the catch of the previous year. This scarcity was reflected in the price which increased from an average of 2.8 cents a pound in 1936 to 5.1 cents a pound in 1937 (Boston, Gloucester, and Portland landings). All other species decreased sharply in value except redfish which showed a slight increase.

In spite of the increased fishing capacity of the groundfish fleet from the construction of new boats, the haddock catch continued the decline begun in 1936. Preliminary calculations indicate that this decrease was due to a decline in catch per unit of effort of about 20 percent on Georges Bank and 26 percent on the Nova Scotian banks. This is the first decline on the former since 1933, and the third consecutive year of decrease on the latter. The total catch declined 5 percent from the 1936 total of 144,000,000 pounds.

General adoption of the Bureau's recommendation of large-meshed or "savings" gear for otter trawls took place in the spring of 1937 as the result of a voluntary agreement among the operators of New England otter trawlers. Owing to the lack of personnel, it has not been possible to make further observations on the use and performance of this gear, but reports indicate favorable results when properly used.

As during 1936, biological investigation was confined primarily to haddock and mackerel, while many other important species could not be covered owing to limited personnel and facilities. Among these were cod, second in importance only to haddock in the New England fisheries; redfish, flounders, pollock, and whiting. Additional knowledge of the yield and life history of all of these species is needed, for they are being subjected to increasingly intensive exploitation.

The exploratory shrimp trawling carried on in the Gulf of Maine in 1936 (described in Memorandum I–57) has not yet resulted in the development of a commercial fishery of any size. Occasional reports indicate growing interest in this resource which may eventually lead to the development of a considerable small boat fishery during certain seasons of the year.

Works Progress Administration Project No. 165–14–6999, begun in 1936, was terminated in July 1937. When the project came to an end, the mackerel and shorefish work was about completed, but considerable work remained on certain parts of the haddock project and on the compilation and charting of the data assembled on the project covering statistics of the New England fisheries.

The headquarters of the North Atlantic Fishery Investigations has remained in Cambridge and Boston, Mass. Harvard University has generously provided the staff with space and facilities in its Biological Laboratories. The cooperation of the Woods Hole Oceanographic Institution is gratefully acknowledged, as is the personal advice and interest of Prof. Henry B. Bigelow. The assistance and cooperation of fishermen and dealers in providing the use of their records, and in other ways, is also acknowledged with pleasure.

HADDOCK

The year 1937 witnessed no striking new developments in the New England haddock fishery although several trends indicated in earlier years became more pronounced. The increase in the otter-trawl fleet begun in 1936, continued with the addition of 10 large otter trawlers. These additions were partly counterbalanced by the withdrawal from active service of several old steam trawlers, but the total fishing capacity of the fleet was greater than at any other period in its history. In spite of this increased fishing effort, the total groundfish catch landed at Boston, Gloucester, and Portland by vessels of 5 net tons or over dropped about 2 percent from the all-time high of 386,000,000 pounds reached in 1936, and the catch of haddock, as noted above, decreased 5 percent from the 1936 total of 144,000,000 pounds. This decrease in haddock landings also was accompanied by a decrease in average value to the fishermen from 3.1 to 2.8 cents a pound with the result that the total value of the haddock catch dropped about 14 percent below that of the previous year.

The past year also showed a continuation of the trend toward a broadened base for the otter trawl fishery in terms of kinds of fish utilized, resulting from the lack of sufficient haddock to supply an expanding market, the use of modern processing methods which prepare the various species in equally convenient form, and changes in the market as the result of the above factors. In 1929, 66 percent of the catch of the groundfish fleet consisted of haddock. By 1937, owing largely to the increasing catch of other species, the proportion of haddock had decreased to 36 percent, while redfish had increased from 0 to 15 percent, and cod, pollock, whiting, and flounders showed smaller increases. Partly as a result of this shift to other species during periods when haddock were scarce, and partly owing to the increased use of frozen fillets, haddock price fluctuations have been greatly reduced.

This fundamental change in the groundfish market should have significant repercussions in the fishery for haddock and other species. In the past, with the mass production market concentrated on one kind of fish, it was possible for the commercial fishery to reduce the average abundance of that species far below the level of others found in the same general region. With the present development of a less specialized market this should no longer occur. Increased scarcity of one species will cause a shift in fishing intensity to another before severe depletion occurs, with the result that the abundance level of the various marketable species will tend to fluctuate together.

With the above developments the haddock problem in many respects becomes a groundfish problem, for it no longer will be possible to explain or predict fluctuations in the haddock catch on the basis of the haddock population alone. The general condition of the other major commercial species must also be known. This extension of the catch analysis is one of the most pressing requirements of the investigation. Continued progress toward the accurate prediction of catches and rationalization of the fishery requires understanding of the abundance of cod, redfish, and pollock as well.

Progress of investigation.—The haddock investigations are designed primarily to provide an accurate measure of the extent and cause of changes in abundance and to develop a practical plan of exploitation that will maintain the yield at the optimum level. Accurate figures of total haddock catch are collected for each major fishing area in cooperation with the Division of Fishery Industries. Assembled records of total catch show that haddock landings at principal New England ports increased from about 60,000,000 pounds in 1921 to nearly 250,000,000 pounds in 1929, dropped to 140,000,000 pounds in 1932, and have since then fluctuated about that level.

The relative abundance of haddock from year to year is being studied through the detailed analysis of the catch records of three groups of trawlers. This yields an accurate measure of their average "catch per day's fishing." Extensive and detailed analysis of otter trawl catch records demonstrates that in the Georges Bank-South Channel region the catch per unit of effort more than doubled between 1923 and 1927, then dropped precipitously to one-fifth that value in 1931. Catch per unit then gradually increased to a level in 1936 nearly double that found 5 years earlier, but little more than one-third as high as during the 1927 period.

Fluctuations in total catch have been due to changes in the abundance of haddock on the banks and to changes in the amount of fishing effort expended. Fluctuations in abundance, as measured by "catch per day," have been primarily due to differences in the numbers of young haddock produced during successive spawning seasons, combined with a rapid depletion of the stock of older fish due to the very intensive fishery.

Growth rate on the various fishing grounds is studied through the analysis of length frequency data and scales regularly collected on the Boston Fish pier and at sea on commercial trawlers and on research vessels. Because of the limited amount of time available for the study of growth rates only general conclusions may be drawn. The growth rates on the different parts of Georges Bank differ considerably among themselves, but when samples are considered *en masse*, the growth is seen to be considerably greater than on the Nova Scotian banks, especially for the younger sizes. Over the entire haddock range covered by the New Egland fishing fleet growth appears to be greatest in the South Channel region and least on Banquereau.

Passive migrations of haddock eggs and larvae have been studied through the systematic sampling with plankton nets of the egg and larval population in the South Channel-Georges region and through the determination of ocean currents by the use of drift bottles, water temperatures, and densities. It has been found that the principal spawning center is on eastern Georges Bank, with a smaller one in South Channel. The eggs from eastern Georges Bank drift to the southwest, where they hatch, part of the larvae being caught in a current circling to the northeast around Georges Shoals. These young fish presumably go to the bottom in this region, and by the end of the winter are found principally on southeastern Georges Bank. The eggs and larvae not caught in the northeast current are carried to the westward toward Long Island, where they presumably perish, for no young haddock have been found on the bottom in this region. The data indicate that no appreciable number of eggs and larvae reach Georges from other banks, demonstrating that this area is a self-contained unit insofar as the supply of young is concerned.

Most of the information concerning the active migrations of older fish is derived from analysis of length and age data. Results indicate that there is no movement of young haddock between Georges and the Nova Scotian bank, but that a limited intermixture of the older fish takes place. For practical considerations the populations of the areas east and west of the Fundian Channel may be considered independent.

The relative abundance of year classes is being determined through the age analysis of the commercial catch and of material collected on the *Atlantis* trawling trips in 1935 and 1936 through the cooperation of the Woods Hole Oceanographic Institution. The haddock work is urgently in need of facilities for continuing such deep sea trawling to determine the abundance and distribution of 1-, 2-, and 3-year-old haddock, as it is becoming more and more evident that major changes in both the distribution and size of the catch depend on the abundance of these smaller sizes during the previous year.

During 1937 the haddock work continued under the direction of W. C. Herrington, assisted by J. R. Webster and H. M. Bearse. Principal effort was concentrated on the collection of accurate data showing the total amount of haddock taken from each fishing ground, the continuation and improvement in accuracy of the determination of catch per unit of fishing effort, the analysis of catch records going back to 1914, to obtain a similar measure of haddock abundance for comparison with the present trend, analysis of length and scale data to determine growth rates and mass intermigrations, and analysis of material collected on *Atlantis* trawling trips in 1935 and 1936, to show changes in the composition of the population on Georges Bank, sex ratios, growth rates, and migrations.

Field work to a large extent was limited to the Boston Fish Pier, where Mr. Bearse continued the collection of data. Information for each boat and trip showing sailing date, landing date, and areas fished was supplied to the Division of Fishery Industries and incorporated in its statistical reports. In addition to the above field work, trips were made on the trawlers *Winchester* and *Fordham* to obtain catch data.

Although all of the statistics for 1937 are not yet available, it is possible on the basis of 8 months' data to estimate the changes in the haddock population that affected the commercial fishery in 1937. The abundance as indicated by average catch per day in the Georges Bank region decreased about 20 percent, while that on the Nova Scotian banks decreased about 26 percent. As a result of the relatively poorer yield from the latter area, the fleet spent an increasing proportion of its fishing time on Georges Bank, and this together with the increased fishing capacity resulting from the construction of new boats, resulted in an increase in the total catch on Georges Bank from 75,500,000 to 83,000,000 pounds, a rise of 10 percent, in spite of the decreased abundance. Apparently the decrease in the proportion of time spent on the Nova Scotian banks about equalled the increase in effort from the addition of new boats, for the decline in catch (25 percent) approximated the decline in catch per day (26 percent).

The downward trend in abundance on Georges Bank followed moderate increases in 1934, 1935, and 1936, while on the Nova Scotian banks the downward trend marked the third year of decline, a total drop in catch per day (by weight) of about 33 percent since 1934. The year 1937 also marked the return of the bulk of fishing activities to Georges Bank. During the 1929 period this area supplied around 90 percent of the total haddock catch, but this share had dropped to 30 percent in 1934, as the fleet sought more distant fishing grounds to maintain its catches. Following 1934, the fishery again swung back to Georges as the result of decreasing abundance on the Nova Scotian banks and the relatively better conditions on Georges, with the result that the proportion of the catch supplied by the latter increased from 30 percent in 1934 to 40 percent in 1935, 52 percent in 1936, and 61 percent in 1937.

Analysis of records prior to 1923 to yield catch per day figures comparable to present data has proceeded, but is not yet complete.

Further analysis of the data collected on *Atlantis* trawling trips in 1935 and 1936 in conjunction with data from the commercial catch indicates that the exploratory trip in 1935 did not provide a representative sample (in respect to age and size composition) of the Georges Bank population, but that the 1936 data were much better. The work clearly demonstrates that the commercial fishery does not sample all sizes of marketable haddock in equal proportions. Owing to the price differential between large and scrod haddock, the former generally are over-sampled. It is concluded that field work of the kind carried on from the *Atlantis* is absolutely essential to supplement data from the commercial catch. Such work makes possible an estimation of the relative abundance of 1-, 2-, and 3-year haddock which are not sampled by the commercial fishery; provides information concerning the haddock populations in areas not fished by the trawling fleet because the fish are too small or too scattered; and gives some check on the accuracy with which the commercial catch samples the population. In addition, many valuable data are obtined on growth rate, sex ratio, and distribution.

Considerable progress was made in combining and summarizing length-frequency data collected in 1936 and 1937. One-month and 4-month summaries by subareas have been prepared so that the data now are ready to be broken down into age classes. Analysis of scale samples was confined to the *Atlantis* collections and contributed to the results discussed above. During the work on length frequencies, a careful analysis was made to determine the most satisfactory method for sampling the commercial catch and for combining the samples. The results of this investigation were reported in a paper read before the American Statistical Association.

Prospects for 1938.—In Progress in Biological Inquiries, 1936, it was stated that in 1937 a moderate decline in catch per unit of effort on Georges Bank might be expected while the total catch should increase somewhat. The catch per unit actually decreased about 20 percent (8 months' data) while the total catch increased 10 percent. For the Nova Scotian banks it was predicted that there would be a considerable decline both in catch per unit of effort and in total catch. The catch per unit actually decreased about 26 percent (8 months' data) while the total catch decreased about 25 percent.

In view of the facts that analysis of 1937 data is not yet completed and that data on the abundance of the 1936 class (which will reach marketable size in 1938) are lacking, it is impossible to make definite predictions for the 1938 season. The catch per day both in the Georges Bank region and on the Nova Scotian banks will undoubtedly be considerably less than in 1937 unless there is a great influx of scrod during the summer and fall (1936 class on Georges Bank and 1934 class on the Nova Scotian banks). Unfortunately, the relative abundance of these classes on the grounds mentioned is not known, for the members of these groups were too small to be taken in significant numbers by the commercial trawlers during 1937 and no boat was available for special trawling trips such as were made on the *Atlantis* in 1935 and 1936. Unless the 1936 and 1934 classes appear in unusual abundance, it appears that the decline in catch per day will be sufficient to cause a considerable drop in total haddock catch in spite of the increase in the size of the fleet.

MACKEREL

Although statistics for the 1937 mackerel season on the Atlantic coast are not completely assembled, a fair estimate of the total United States vessel catch lies between 14 and 15 million pounds. This is the poorest catch since 1922, when landings by vessel fishermen were about 9,000,000 pounds. The 1937 catch falls about 65 percent below 1936, when some 40,000,000 pounds were landed at eastern ports.

This great decline brought serious consequences. Many fishermen who usually depend upon the mackerel fishery for their livelihood during a great part of the year were forced either to engage in some other fishery, such as dragging, or to continue after mackerel at negligible profit. The majority of the fleet adopted the latter course. In either case, the financial return was reduced greatly under expectations. Another aspect of the situation is well illustrated by cold storage statistics. During the previous 5-year period, the New England and Middle Atlantic cold storage holdings of mackerel reached a maximum in September or October. This reserve, which averaged 10,000,000 pounds, was built up during summer and early fall when prices were low. In October of 1937, on the other hand, less than 2,000,000 pounds were in storage, and even after continued speculative purchases at high prices, the maximum holdings attained were but 3,000,000 pounds by the end of the year.

In the light of developments during 1937, the necessity for an accurate mackerel catch forecast stands out more than ever before as an important fisheries problem. The biological basis for any successful prediction of catch must be a sound knowledge, not only of the mackerel, but also of its environment. Acquisition of such knowledge has occupied the principal attention of the mackerel investigators during the past 10 years and a report is now in preparation covering results of the work through 1936. Briefly summarized, they are as follows (O. E. Sette, Report to the North American Council on Fishery Investigations, September 1937):

Winter home.—The species winters along the edge of the continental shelf, most probably from the offing of Chesapeake Bay to the Fundian Channel, and possibly as far east as Sable Island Bank. When in the winter habitat, mackerel probably are in mid-depth rather than on bottom or at the surface.

Migrations.—The population migrates in two divisions: a southern contingent that moves shoreward between Chesapeake and Delaware Bays in April, thence northeastward along the coast to the Gulf of Maine, in the western part of which it spends its summer, returning southward around Cape Cod in late October; and a northern contingent that moves shoreward toward the coast of southern New England in late May, thence northeastward across the Gulf of Maine, along the Nova Scotian coast, and into the Gulf of St. Lawrence where it spends the summer. This division is believed to emigrate along the Nova Scotian coast and through the western portion of the Gulf of Maine (where it supports an important November drift-gill-net fishery) and out to sea past Cape Cod. The northern contingent, when migrating along the Nova Scotian coast in the spring, may be joined by additional members from directly offshore and when leaving in the fall may lose members in an offshore direction if any winter as far eastward as the outer edge of the Nova Scotian banks. Both southern and northern contingents leave stragglers behind them along their migratory routes so that some mackerel, usually the smaller adolescent individuals, populate the coasts of southern New England and Nova Scotia, even though the main bodies are in the Gulf of Maine and the Gulf of St. Lawrence.

Horizontal distribution.—During the summer sojourn mackerel predominantly inhabit the open waters over the inner part of the continental shelf. Important numbers are regularly found neither in enclosed bays nor in far offshore positions. The waters of the deep central portions of the Gulf of Maine are particularly avoided and catches are only occasionally made over the offshore banks. Larger individuals tend to be farther offshore than smaller ones.

Vertical distribution.—The marked thermocline established in spring and persisting through summer forms the lower boundary of mackerel distribution, the underlying colder water imposing an effective barrier to downward movement. Variations in position and intensity of the thermocline affect the success of the fishery.

Schooling habits.—Mackerel are usually aggregated in dense schools—a form of association that probably is advantageous in feeding on plankton. The lesser swimming ability of smaller individuals, resulting from the relation between volume of muscle and surface area, causes a marked but variable schooling according to size.

Feeding habits.—The American representatives of the species feed almost entirely on plankton, but additional observations are needed relative to large offshore individuals, which, like their European relatives, may subsist on small fishes during the late summer and autumn months.

Spawning.—The inner portions of the continental shelf between Cape Hatteras and Cape Cod form the most productive spawning ground; next is the southern half of the Gulf of St. Lawrence. Spawning in intermediate areas is of slight importance excepting perhaps the southern part of Massachusetts Bay which has high concentrations of eggs in spite of its small area. Spawning takes place in April and May south of Cape Cod, in May and June in Massachusetts Bay, and in July and August in the Gulf of St. Lawrence.

Early life history and growth.—Eggs hatch in 3 to 8 days, depending on temperature. The earliest post-planktonic individuals to be found during the course of the investigations were 2 to 6 inches long in the latter part of July. By the end of the first season mackerel are 7.5 to 10.25 inches long; by the end of the second season, 10 to 14 inches long. Thereafter, growth is slower. By the tenth year mackerel average about 18 inches in length, and weigh 2 to 2½ pounds.

Although many of the more important features of mackerel biology are fairly well understood, and by themselves will furnish a reliable catch forecast in some years, the fact that environmental conditions exert a profound effect upon the actual catch was well illustrated this year. In the annual prediction for 1937, it was estimated that the abundance of mackerel would be about 80 percent of the 1936 level. The actual catch, however, reached about 35 percent of the 1936 level. The difference appears to have been due chiefly to inability of purse-seine fishermen to find fish in the usual localities.

The spring run fell under expectations, but not to an alarming degree. During summer, the decrease was more pronounced. Purse seiners found schools unusually scarce and close to shore, their operations being hampered at times by shallow water. At the same time, shore-trap operators enjoyed their best mackerel catches in many years. The mackerel populations were not wholly centered along the shore, however, since otter trawlers on Georges Bank caught unusual numbers of them incidentally throughout the summer, evidence of a relatively large offshore dispersal. Furthermore, many observers noticed a scarcity of *Calanus*, the favorite "red feed" of mackerel, on the usual mackerel feeding grounds. This may explain the scarcity of mackerel in these areas. Reasons for the scarcity of *Calanus* are not known but unusually warm ocean temperatures offer a possible explanation.

The fall mackerel season showed evidence of improvement in October, and in November the landings, though small, were greater than in the previous year. This improvement preceded an event which made fishing history, a continuation of mackerel seining into January 1938.

Mackerel work during 1937 was continued under the direction of O. E. Sette. Field data were collected principally by F. E. Firth. These comprised 534 interviews to obtain information on individual trips, measurement of 36,139 mackerel for length frequency analyses, and collection of 1,135 scale samples. In October, O. E. Sette, who had directed the North Atlantic investigations and conducted the mackerel work since 1926, was transferred to the Pacific coast. It is expected that a comprehensive report covering the results of his investigation will be ready for publication during the coming year. J. R. Webster has been assigned to continue the mackerel work in 1938.

MIDDLE AND SOUTH ATLANTIC FISHERY INVESTIGATIONS

R. A. Nesbit, *in charge*

The fisheries of the Middle and South Atlantic States offer an opportunity to realize substantial benefits from scientifically controlled management. It is difficult to escape the conclusion that these fisheries have been exploited inefficiently for many years. In spite of developments which might be expected to increase production, such as the expansion of markets through population increase in the Seaboard States, technical improvements in fishing methods and distribution facilities, extension of intensive fishing activities to areas not previously fished, more intensive fishing on the older grounds, and development of markets for species not previously utilized, the production of food and game fishes has not merely failed to increase but has actually declined during the present century.

This situation is undoubtedly an illustration of the modern theory of fishing exploitation which states that in the long run a fishery of moderate intensity will, by maintaining a high level of abundance, produce an annual crop at least as great and usually greater than an excessive fishery, and at a much lower cost. Statistical records show that the less intensive fishery of 40 years ago actually did produce more than the fishery of the present day. Since the only source of real income from the fishery is the difference between the sale price of the product and the cost of production, it follows that a moderate, hence low cost, fishing could provide employment either for the present number of fishermen at a higher income level or for more fishermen at the present standard of income, and in either case with a substantial reduction in the hours of labor per fisherman per year.

In addition to the economic gain to the commercial fisheries, restoration and maintenance of high levels of abundance will also improve angling conditions. Many species, including bluefish, weakfish, fluke, winter flounders, sea bass, scup, tautog, kingfish, croaker, striped bass, tuna, and swordfish, support a great recreational fishery which is growing in importance.

Although the objectives of fishery management in this region are clear, the problem of devising and enforcing measures to accomplish them is extremely difficult. A horizontal reduction in fishing activity in all localities and by all methods of fishing would not lead to maximum efficiency, nor would a return to the fishing and distribution methods of 40 years ago. The gross yield of the fishery is the aggregate of the yields of many species which differ greatly in life histories and habits and in their capacity to withstand the effects of the fishery. Most of the important types of gear, such as pound nets, otter trawls, purse seines, haul seines, and gill nets, take more than one species. Consequently, modifications of fishing methods and fishing intensity which would lead to maximum efficiency for one species might result in inefficiency through incomplete utilization of other species.

It is the object of the scientific investigations of the Bureau to devise equitable and practical means of maintaining adequate numbers of spawners and of harvesting the crop produced by each year's spawning as nearly as possible at the size and age at which the greatest yield in pounds can be taken with the minimum fishing effort, i. e., at the lowest cost.

For the present, at least, the most profitable field for the application of fishery management practices appears to be that of eliminating as far as possible the present wide spread destruction of fish too young to be marketable and marketing of fish which would be more valuable if allowed to grow to larger sizes.

It is recognized that many difficulties exist. The diversity of sizes and shapes of the several species taken by pound nets, seines and otter trawls renders it difficult to permit the escape of undersized fish by increases in the mesh size of the netting, for meshes which allow the escape of the young of large species may also allow legitimately marketable sizes of smaller species to escape. In some localities at least, increase in the sizes of mesh would result in great inconvenience in fishing through the gilling of certain sizes in the meshes. However, many species, including scup, sea bass, striped bass, winter flounders, and fluke, are sufficiently hardy that the majority would survive the handling incident to sorting. Steps should be taken to require that catches by pound nets, seines, and otter trawls be sorted as soon as they are taken from the net, wherever and whenever conditions of weather and tide permit, even at the cost of some inconvenience and delay in removing catches from the nets.

If this line of attack on the conservation problems of the region be adopted by even a few of the several States in which jurisdiction over territorial waters is vested, the expected benefits will not be wholly nullified by failure of adjacent States to adopt similar measures. In this respect the proposal differs from plans to restrict the catch of the larger and more desirable market sizes, for unless closely coordinated action be taken by all of the States concerned restriction in a single State may be expected to stimulate fishing in adjacent States so that little or no reduction in the catch of the larger sizes from the migratory population as a whole may be expected.

Until October 1937 scientific activities in the Middle and South Atlantic region were administered from the headquarters of the North and Middle Atlantic Fishery Investigations at Cambridge, Mass. In October headquarters were established in the Horticulture Building of the University of Maryland at College Park, Md., under the direction of R. A. Nesbit. The courtesy of the University in providing office and library facilities without cost to the Bureau is gratefully acknowledged. W. C. Neville is carrying on the investigations of shore fishes of the Middle Atlantic States, formerly under Mr. Nesbit's supervision, although Mr. Nesbit is continuing analysis of squeteague data. Field headquarters for study of the shad fishery were established in the Charleston Museum, Charleston, S. C., office and laboratory facilities being generously provided by the Museum. John C. Pearson is in charge of the Charleston office, assisted by Louella Cable, Charles O. Hathaway II, and Oliver A. Duff.

SHORE FISHES

Field observations of this group of species have been conducted on a greatly reduced scale since 1932, when economies in administration were effected.

To a large extent this reduction in Bureau activities has been compensated for by increased scientific studies by the conservation departments of several States in the region, working in cooperation with the Bureau's staff. Rhode Island has established a laboratory in Narragansett Bay. The Rhode Island investigators, under the direction of Dr. Charles Fish, Professor of Zoology in the Rhode Island State College, have cooperated in a program of tagging winter flounders and have begun valuable studies of the survival of flounder fry planted by the hatcheries. Connecticut has sponsored an investigation of striped bass, preliminary results of which were published during the year. New Jersey has undertaken tagging experiments with young striped bass salvaged from condenser screens in Delaware Bay. Maryland has established an effective scientific organization under the supervision of R. V. Truitt, Professor of Zoology in the University of Maryland and director of the Chesapeake Biological Laboratory. Good progress has been made in studies of shad and striped bass. North Carolina has contributed substantially to the cost of the cooperative striped bass investigations conducted by Connecticut.

In New York the biological survey for 1938 will cover the marine district. Mr. Neville has devoted much time in 1937 to conference with the scientists of the New York Conservation Department in order that the 1938 survey may benefit by the experience of Bureau investigators in this area.

Investigations were conducted by the Middle and South Atlantic staff during 1937 as follows:

Squeteague.—Two thousand two hundred squeteague, mostly yearlings, were tagged in June and early July in Pamlico Sound, N. C. This experiment was planned to test the view, suggested by scale studies and other observations, that the unmarketable yearlings destroyed in Pamlico Sound in the early summer include many individuals spawned the previous year in more northern waters which, if spared, would migrate northward in midsummer. Contrary to expectations, all of the recaptures in 1937 were made locally in Pamlico Sound. This was doubtless caused by the unusually mild winter. Young squeteague spawned in northern localities were not driven as far south as usual during the winter but struck in to the shores in spring much farther north. Unprecedented numbers of yearling squeteague were observed in the spring and summer in New York and the scales of the Pamlico Sound yearlings indicated that few, if any, fish of northern origin were present. This is in marked contrast to the early summer of 1935 when about one-third of the Pamlico Sound yearlings were found to be of northern origin. This tagging experiment will be repeated following a more nearly normal winter.

Scup.—Continued large catches by both winter and summer fisheries indicate that the series of successful spawning seasons which began in 1927 are still continuing. The wasteful practice of destroying large numbers of small scup which persists will accentuate the decline which may be expected to occur when this series is broken.

Progress on Mr. Neville's report on this species was interrupted by additional duties arising from change of headquarters from Cambridge, Mass., to College Park, Md.

Winter trawl fishery.—Mr. Neville spent the greater part of January, February, and March 1937 aboard trawlers engaged in this fishery. His observations indicate that the problem of devising savings gear to spare small fish now wasted by the fishery is so complex that extended experiments will be required. A research vessel equipped for trawling or sufficient funds for charter of a commercial trawler will be required before this work can be undertaken.

Winter flounder.—This species is the basis of a commercial fishery in New York and southern New England and of an important angling fishery in Rhode Island, Connecticut, and New York. Tagging experiments were made in Great South Bay, New York, and in various localities in the vicinity of Narragansett Bay, R. I., to measure the intensity of the fishery and the distribution of the strain between sport and commercial fisheries, and also to determine whether the migrations of these fish are sufficiently limited that conservation regulations by individual States would be practicable. Rhode Island scientists cooperated in the Narragansett Bay experiments. Of the 1,718 flounders tagged during the last week in April 1937, in Great South Bay, 304, or 18.6 percent had been recaptured up to January 1, 1938. About four-fifths of the tagged fish recaptured were taken by anglers and about one-fifth by commercial fishermen. Of the 998 winter flounders tagged in Rhode Island, 128, or 12.8 percent, were recaptured in 1937. Of those recaptured, about three-fifths were taken by commercial fishermen and two-fifths by anglers. Practically all of the recaptures from both experiments were made within the territorial waters of the States in which tagging was done, indicating that the benefits of any conservation measures adopted by these States will not be nullified by possible failure of adjacent States to adopt equivalent measures.

Since this is one of the hardier species, it is well adapted to conservation measures based on selective fishing, that is, on protection of those sizes which are more profitably allowed to grow as long as the gains from growth more than balance the losses from natural mortality. Further studies of this species will be directed toward an estimate of the most desirable minimum size limit.

ANADROMOUS FISHES

Striped bass.—In April 1936, an investigation of the striped bass was undertaken through the efforts of the Connecticut State Board of Fisheries and Game. From the first this investigation has been conducted on a cooperative basis. Connecticut sportsmen financed the first 3 months of the work, the State Board of Fisheries and Game then supported the investigation and the American Wildlife Institute contributed a substantial sum in the spring of 1937, when a break in the continuity of the work would have been a severe blow to its progress. In July 1937, the Bureau of Fisheries insured the financial backing of the work for a full year from that date by the employment of Daniel Merriman, who had conducted this work for the Connecticut Board of Fisheries and Game. Several Atlantic seaboard States have contributed to the investigation, and every State from New Hampshire to North Carolina has given its fullest cooperation in some phase of the work. Particularly is this true of Maryland, with its concurrent investigation on the striped bass under Dr. Vadim D. Vladykov. The cooperation of North Carolina, through Mr. Chalk, Commissioner of Inland Fisheries, and of various Long Island fishing clubs has been invaluable. Massachusetts sportsmen have led the way in collecting material on the striped bass through the efforts of David A. Aylward, secretary of the Massachusetts Fish and Game Association, and Oliver H. P. Rodman, editor of Hunting and Fishing.

In colonial times the striped bass was very abundant along the whole Atlantic coast from North Carolina to Nova Scotia. By 1850, it had greatly declined in abundance and in recent years it has been almost a rarity north of Chesapeake Bay. The decline was less marked in the latter locality and in North Carolina, although serious enough especially in the years between 1930 and 1936, to cause concern.

In 1936, however, unusual numbers of 2-year-old striped bass appeared in Chesapeake Bay and also in New York and in southern New England. Catch records indicate that abundance was greater in the latter localities than at any time during the preceding 50 years. In Chesapeake Bay the large catches of 2-year-old fish were preceded in 1935 by a great abundance of yearling bass, but careful inquiry failed to disclose any evidence of a similar phenomenon in the more northern localities. Tagging experiments showed that many of the 2-year-olds which summered in Connecticut in 1936, migrated southward in the autumn, some of them as far as the sounds of North Carolina.

These observations indicate that this species is subject to strong year-class dominance and that bass migrate more than was formerly suspected. It is of especial significance that the large 1934 brood was produced in a year when the numbers of mature adults were not only no greater than during the several years preceding, but were also well below average. Consequently, the restriction of the catch of mature striped bass in the interest of augmenting the spawning reserve is of doubtful value even in such localities as Chesapeake Bay, where reproduction is occasionally very successful. It is even more questionable whether protection of mature fish will be profitable in more northern localities where the principal increments to the stocks appear to come from immigration.

This does not imply that the present practice of virtually unrestricted fishing is desirable. Results of tagging experiments indicate that the fishery takes a very heavy toll of successful broods before they mature. It is believed that restriction of the catch of the younger and smaller fish would increase the total yield from each brood and would incidentally augment the numbers of spawners.

Shad.—The gross catch of shad has declined from nearly 50,000,000 pounds in 1897 to less than 9,000,000 pounds in 1935. It is inconceivable that the decline in yield of this choice species does not indicate diminished abundance. Since the shad is not subject to commercial fishing during its period of growth in the sea, the causes of depletion must be sought in human interference with spawning migrations into coastal rivers.

The following explanations of diminished reproduction have been offered: (1) interference with spawning by pollution and by obstruction of streams by dams; (2) insufficient numbers of spawners resulting from over-fishing. It is not to be doubted that complete blocking of the Susquehanna River by the Conowingo dam has eliminated a considerable spawning area and it is probable that severe pollution in the Delaware has at least contributed greatly to a virtual disappearance of the shad runs in that stream. On the other hand, a number of rivers which are almost completely free from pollution have shared in the general decline and the Hudson River, which certainly cannot be said to be unpolluted, has staged a most spectacular recovery, the catch increasing from less than 100,000 pounds in 1917 to a yield of nearly 3,000,000 pounds in 1936.

The recovery of fishing in the Hudson River is attributed by the New York Conservation Department to the measures which it has adopted to insure that sufficient numbers of spawners are allowed to escape the fishery. On the other hand, it is believed by many that the shad is highly migratory in its habits and that the increased runs in the Hudson River are merely the result of a desertion of southern rivers by the stocks which usually seek them.

The former explanation seems more likely but decision must be reserved until the results of tagging experiments, scale studies and other tests of the parent stream hypothesis are available. Consequently, considerable effort will be devoted in 1938 to such observations and experiments.

A preliminary experiment in October 1937, indicated that when young shad about 2½ inches long are marked with internal tags, about one-third survive the initial shock of handling and operation. Unfortunately, the survivors as well as unmarked controls eventually succumbed to unfavorable aquarium conditions so that it is not known whether such tags will be retained indefinitely. Further experiments will be made in 1938.

An attempt will also be made to tag spent shad to determine whether they return to the same stream each year.

If, as is probably true, the increase in abundance in the Hudson River is the result of regulations which permit an adequate escapement of spawners, the numbers of shad spawning in the Hudson River for the second or third time should be greater than in the seriously depleted southern streams. There are present on some shad scales eroded bands resembling the spawning marks of salmon. If these prove to be spawning marks and if examination of the scales of spent shad indicates that spawning invariably results in the formation of such marks, it is expected that comparison of the numbers and the percentages of "repeaters" in the Hudson River and in southern streams will serve as a basis for judging the effectiveness of such regulations as may be adopted in the southern areas.

A serious obstacle to effective study of the shad fishery is the lack of detailed records of the catch. Better records of the total catch will be needed to convert the estimates of the percentages of "repeaters" into estimates of the actual numbers of spawners escaping the fishery. Records of changes in abundance in terms of catch per unit of fishing effort will be needed in order to follow in detail the results of such regulations as may be recommended. To correct this lack of data, collection and analysis of shad catch records were begun in the Chesapeake region by Ferdinand C. Latrobe and in South Carolina by Oliver A. Duff. The conservation officials of Maryland, Virginia, and South Carolina and the staff of the Bureau's Division of Fishery Industries are cooperating in this work.

Should it eventually appear that provision for an adequate reserve of spawning adults is the principal requirement for maintenance of abundance, the problem of determining the optimum escapement will be of primary importance. Protection of spawners in excess of the numbers needed for reproduction is obviously wasteful, and inadequate protection prevents full realization of the productive capacity of the resource. An attack on this problem was begun by initiation of studies of early life history of the shad in the Edisto River, S. C., by John C. Pearson, assisted by Charles O. Hathaway II. Louella Cable also began studies of the plankton cycle and the food habits of young shad in the same river.

It is notable that many years of artificial propagation have failed to halt the decline in abundance of shad. Although it is possible that the decline would have been much greater had hatcheries not been operated, it is desirable to test carefully the effectiveness of present methods of artificial propagation and to experiment with methods of carrying fry to the fingerling size. A beginning on such a program of investigation was made by Mr. Pearson at the Edenton, N. C., hatchery. Pond and laboratory facilities have been placed at his disposal at this hatchery and at the Orangeburg, S. C., hatchery by the Division of Fish Culture.

SHRIMP INVESTIGATIONS

MILTON J. LINDNER, *in charge*

During 1937, as in preceding years, the shrimp investigations have enjoyed the cooperation of the Louisiana Department of Conservation, the Texas Game, Fish and Oyster Commission, and the Georgia Department of Natural Resources. The San Patricio Canning Co., of Aransas Pass, Tex., has continued to furnish office space for the Texas investigator. In addition, the City of Gulfport, Miss., during the past year supplied dockage and locker space for the *Pelican.*

There has been a steady addition to the shrimp fishery of new, larger, and more powerful boats drawing larger trawls. This continued increase in fishing effort has been under way for the last several years and is especially evident on the Atlantic coast. The expansion of the fishing fleet, both in size of the individual boats and in their aggregate numbers, has resulted in an increase in its fishing radius.

The South Atlantic fishery.—The Atlantic fleet, comprised mainly of boats originating in Florida, moves along the coast from North Carolina to Florida with the concentrations of shrimp. As a general rule the summer and early fall fishery is most productive between North Carolina and Georgia. During late fall and winter, however, the shrimp and the fishing fleet are concentrated in the area between St. Augustine and Cape Canaveral, Fla. During the past several years, owing to intensive fishing in more northern areas by the rapidly expanding fleet, the Florida winter fishery has diminished in importance. It appears evident that the greater part of the shrimp are being caught before they reach central Florida. As a result, it is expected that a portion of the Atlantic fleet will move into the Gulf during the winter of 1937–1938.

While the supply shows no signs of serious depletion, the South Atlantic shrimp fishery seems to have reached the maximum of production possible under the present system of management. Although the total catch has not declined, neither has it increased with the augmented fishing effort. Obviously, if more and more gear continue to enter the fishery, the economic stability of each unit will be lowered and a number of the marginal units will find it unprofitable to operate.

From our present understanding of the shrimp it appears that an increase in the total poundage taken by the South Atlantic fishery can be secured only through better protection afforded the young. The intensified fishery is making greater inroads on the young shrimp, a condition which in turn will cause a reduction in the total pounds landed, even though depletion may not occur. As fishing intensity increases, shrimp fishing will therefore become poorer from the viewpoint of the fisherman.

Tagging experiments conducted by William W. Anderson during the past several years have shown that the larger Georgia and South Carolina shrimp move south into Florida during the winter. During the fall of 1937 shrimp were tagged and released over practically the entire northern range of the fishery in order to determine whether or not large individuals from the northern limits also migrated south to become a part of the Florida winter fishery. Tagged shrimp were released along the coast from Beaufort, N. C., to Brunswick, Ga. Returns have been secured in Florida from these releases, showing that at least some of the North Carolina shrimp normally migrate to Florida during the winter. Apparently then, the South Atlantic shrimp fishery should be considered as a single unit rather than as separate fisheries, each limited within the boundaries of one of the several States involved. Any regulatory measures or lack of regulations in one section will affect not only that section but other portions of the fishery as well; hence, it is advisable that the States of North Carolina, South Carolina, Georgia, and Florida attempt a cooperative management of their shrimp fisheries, with regulations as nearly uniform as possible.

Present knowledge of the movements of shrimp suggests many additional questions. What is the fate of the large shrimp that migrate from the northern areas into the Florida winter fishery? Do these shrimp normally return north in the spring to spawn? If there is a return migration, do the shrimp come back to spawn in the locality in which they were reared or is the return more or less haphazard? Is the fishery so intense that practically all the winter migrants are captured before they have an opportunity to return north? What changes can be expected in the future population of shrimp from a more intensive fishery? To what sizes of shrimp and at what seasons of the year can regulatory measures be most profitably applied? Do the shrimp perish at the age of 1 year or is there a breeding reserve in offshore areas beyond the range of the present commercial fishery?

It is expected that the current tagging program will solve many of the problems relating to migrations along the South Atlantic coast. These studies, in addition to yielding positive knowledge of the movements of the shrimp, are supplying data on the intensity of the fishery and the rate of growth of the various sizes of commercial shrimp at all seasons of the year.

The extremely important question of a possible breeding reserve of shrimp more than 1 year of age in offshore waters along the South Atlantic coast cannot be answered satisfactorily however, until exploratory fishing can be performed in the deeper waters. The *Pelican* may be used in such investigations at some future date. Thorough studies of the coastal population show that no breeding reserve is present in any of the coastal areas; therefore if such stock exists it must be in offshore waters.

The Gulf Fishery.—The most striking development in the Gulf shrimp fishery during 1937 was the large summer and fall run in Louisiana and Mississippi. The run was considerably greater than that of the years immediately preceding and was confined to the above-named States. This run further emphasizes the fact that there are good and bad years with respect to the production of shrimp and that the number of spawners is not the important factor in determining production of young. The 1937 Gulf spring fishery which represents the spawning population was extremely poor and barring the possibility of a breeding reserve of shrimp more than a year old remaining in the deeper waters beyond the range of the commercial fishery, a very small group of spawners was successful in producing a large number of offspring. It is highly probable that the effluents of the Mississippi River play an important part in determining the success of spawning.

As stated in several previous reports, there is evidence in the Gulf of an offshore movement of large shrimp during the winter. This migration is comparable in many respects to that of the South Atlantic coast; it differs however, in that it is primarily offshore and outside the present commercial fishing range, whereas the South Atlantic movement is coastwise and within the commercial fishing limits. Early in the year the *Pelican*, a 78-foot Diesel vessel, was transferred to the Gulf for the purpose of making exploratory cruises in order to determine whether or not the winter migrants concentrate in sufficient quantities to permit commercial fishing. Owing to insufficient funds, however, the boat was unable to operate during the fiscal year 1937 and it was deemed advisable to postpone operations until January 1938.

In addition to discovering winter offshore concentrations of shrimp, the work of the *Pelican* should give valuable data on the length of life of the shrimp, whether or not there is an offshore spawning reserve in the Gulf, and the extent of the spawning grounds.

Arrangements have been made with Prof. A. E. Parr of the Bingham Oceanographic Institute of Yale University to analyze the salinity samples secured with the *Pelican*. Similar arrangements have been made with Professors H. V. Howe and R. J. Russell of the Department of Geology of Louisiana State University to analyze the bottom core samples which are taken at each trawling station.

The Texas program which has been conducted by Kenneth H. Mosher has been primarily that of sampling the commercial fishery, but during the past 2 seasons, through the assistance of Albert Collier, Marine Biologist of the Texas Game, Fish, and Oyster Commission, tagging operations have been added.

It is known that temperature and salinity affect the behavior of the shrimp, and during the past year it has been determined that tides also enter as a factor. In the vicinity of Corpus Christi, Tex., it was found that better catches of shrimp, as a rule, were made during periods of low than of high water.

John C. Pearson, prior to his transfer to the shad investigations, submitted for publication a manuscript describing the larval stages of the common shrimp and those of four other peneids. This basic work will be of considerable aid in determining the extent of the spawning grounds.

NORTH PACIFIC AND ALASKA FISHERY INVESTIGATIONS

DR. F. A. DAVIDSON, *in charge*

The North Pacific and Alaska fishery investigations, with headquarters in the Fisheries Biological Station at Seattle, Wash., are confined mainly to the solution of problems concerning the maintenance and rehabilitation of the salmon and herring fisheries of Alaska and the salmon fisheries of Puget Sound and the Columbia River. All of the major investigations in progress in 1936 were continued in 1937.

COLUMBIA RIVER SALMON FISHERIES

Investigations of biological and physical conditions affecting the Columbia River fisheries were continued during 1937 by J. A. Craig and A. J. Suomela. Counts of salmon and steelhead migrating over Rock Island Dam in the Columbia River and into the tributary Okanogan and Wenatchee Rivers were formerly part of this investigation. In 1937, however, this work was taken over by the U. S. Bureau of Reclamation and the Washington State Fisheries Department, under the project concerned with the protection of migratory fish at Grand Coulee Dam. The collection, tabulation, and analysis of catch records of the commercial fisheries in the Columbia River was continued to provide data on the annual and seasonal indices of abundance of fish populations in the river system. During the year a report on the history and development of the Columbia River fisheries, including salmon, sturgeon, shad, and smelt, was submitted for publication.

Tagging.—A tagging experiment was conducted for the purpose of obtaining data concerning the spring, summer, and fall runs of chinook salmon which pass through the commercial fishery from May to September, inclusive. The results of such experiments provide data on the minimum distances which the fish travel upstream to spawn, the proportion of the runs which return to hatcheries, the proportion caught by the commercial fishery above the point of tagging and the speed of migration of the runs after entering the river.

In 1936, a total of 1,059 fall chinooks were tagged and liberated between August 16 and September 2. Tagging this season consisted of 21 experiments from May 17 to September 1, inclusive, in which 1,565 chinooks were tagged. Two of these experiments were conducted at a location 1¾ miles above the mouth of the river and the remaining 19 at a location 5¾ miles above the mouth of the river. The runs of salmon were extremely light during the spring and summer and only a few fish were secured for tagging.

Recoveries of the tagged fish amounted to 381 or 24.3 percent of the total tagged. A few recoveries were taken between the mouth of the river and the point of tagging, but none outside the mouth. A total of 38 tags, or 2.43 percent, were recovered at hatcheries on the Columbia River system. One fish bearing a tag was recaptured in the Toutle River, a tributary of the Cowlitz River. Two tags were observed on fall chinook salmon in the Chinook River but they could not be recovered. The remainder of the tagged fish were caught in the main Columbia River. Tagged salmon were recovered up the river as far as Celilo Falls, 190 miles from the point of tagging.

The results of the experiments in 1937 are now being analyzed. These data, together with the data of the 1936 experiments, will be incorporated in a report to be submitted for publication in the near future.

Stream surveys.—With the exception of surveys conducted on portions of four of the major tributaries of the Willamette River system in the State of Oregon, Columbia River stream survey activities in 1937 were again confined to the State of Washington.

In north central Washington tributaries of the four major river systems, the Okanogan, the Methow, the Entiat, and the Wenatchee, have been surveyed. Fifty minor streams were also examined. In this area a total of 117 dams of all types were found, of which 32 are permanent structures, and 85 temporary. Three of the permanent dams are obstructions at all times, and 21 are barriers at low water only. The number of dams used for irrigation totals 107, of which 23 are permanent and 84 are temporary in nature. Two dams are used for power, 1 for irrigation and power, and 7 for other purposes. There are 143 diversions, of which 133 are for irrigation, 4 for power, 1 for power and irrigation, and 5 for other purposes. In the 34 streams examined in this area, which are part of the 4 major river systems, it was estimated that 35 percent of the river bottom was suitable for spawning purposes, with approximately four-sevenths of this total available to fishes at all times, and three-sevenths unavailable at low water.

In the south central area, the Yakima River system is the only large stream that has been surveyed to date, although 69 minor streams have been examined. In this survey a total of 163 dams were recorded, of which 40 are permanent and 123 are temporary. One hundred and fifty-nine of these are used for diverting water for irrigation purposes and of this number 38 are permanent and 121 are temporary. Five of the permanent dams are complete barriers, 26 are barriers at low water only, and the remainder are passable to fish at all stages of water level. The number of diversions in this region total 280, of which 270 are used for irrigation, 5 for power, 1 for power and irrigation, and 4 for other purposes. In the 34 streams in the south central area that have been examined, it was estimated that 59 percent of the bottom was suitable for spawning, with three-fifths of this total available to spawning fish at all times and two-fifths unavailable at low water.

The survey of the southeastern area of the State of Washington has been completed. This included the following river systems: the Tucannon, Asotin, and Walla Walla Rivers, and 29 minor streams. There were 112 diversion dams in this area, 32 of which were permanent structures and 80 temporary. A total of 172 diversions were found, of which 160 were used for irrigation, 2 for power, 6 for power and irrigation, and 4 for other purposes. In the 17 streams examined it was estimated that 71 percent of the bottom was suitable for spawning, but of this total only one-third was available to fish at all times, two-thirds of the area being unavailable at low water.

The survey of the southwestern area of the State of Washington has not been completed to date. Thus far, a total of 22 dams have been recorded. They are used for the following purposes: 1 for irrigation, 6 for power, and 15 for other uses.

In the State of Oregon stream surveys were conducted on the middle fork of the Willamette River from the proposed flood control dam site at Lookout Point to Tumblebug Creek; on the McKenzie River from the proposed dam site at Quartz Creek to Tamolitsh Falls; on the North Santiam River from the proposed dam site near Detroit to Big Meadows Camp; and on the South Santiam from the proposed dam site at Sweet Home to House Rock Camp at Sheep Creek. During the survey of these streams 4 permanent dams were found, of which three formed partial barriers and one a complete barrier to migratory fishes.

A total of approximately 2,300 miles of stream have been surveyed in the Columbia River drainage up to the present time.. Data derived from all of these investigations were made available on many occasions to interested individuals and organizations, such as State conservation agencies and the National Resources Committee.

PUGET SOUND SALMON FISHERIES

Sockeye.—The Puget Sound sockeye investigation was continued by Dr. George A. Rounsefell.

Daily salmon catch statistics were collected for 1935 and 1936, especially on the Fraser River, where the individual gill net landings were obtained for at least 90 percent of the catch. Daily purse seine landings by boat were obtained for the past 12 years, 1925 to 1936, from Quathiaski, at the northern end of the Gulf of Georgia. It has long been known that a portion of the Fraser River run used the northern route instead of entering through the Strait of Juan de Fuca but no information has been available on its size. In 1936 nearly half a million sockeye were taken in this area. In some years, especially in 1915, 1926, and 1936, the gill nets in the Gulf of Georgia and the lower Fraser River have done much better relatively, than the gear in Puget Sound. Inasmuch as the 3 years in question were extraordinarily warm, it may be possible that the proportion of the run using the northern entrance is largely dependent on temperature. In warm years the sockeye may be feeding farther to the north and so strike the coast in the vicinity of Cape Scott at the northwestern end of Vancouver Island, a fair proportion of the run thus continuing down the inside of the Island.

The usual sampling of the commercial catch was carried on at Anacortes. A feature of the 1937 run was the small average size of the sockeye, which greatly increased the cost of the raw fish to the canneries, as they bought the fish by the piece. The investigation now has available samples of the commercial catch since 1934. The ages of these fish have not been determined pending the completion of this 4-year cycle, but the 1937 scales are now mounted and their reading is under way.

In 1935 the Division of Fish Culture cooperated with the investigation by planting 76,000 fingerling sockeye (1934 egg collection from the Birdsview hatchery on the Skagit River) in Cedar River, a tributary of Lake Washington, and a like number in Issaquah Creek, a tributary of Lake Sammamish, which drains through the Sammamish River into Lake Washington. It is planned during the spring to watch at the Government locks and fish ladder leading into Lake Washington and on the spawning grounds for adult sockeye, to determine whether the plantings were successful in introducing this valuable species. Judging from the available spawning grounds and the general suitability of these lakes to coho and king salmon and to the land-locked kokanee, they might be capable of supporting a sockeye run of fair proportions.

Since it is the duty of the recently formed International Pacific Salmon Fisheries Commission to make a study of the sockeye runs to the Fraser River system it is not planned to collect additional data on this species. Work on the Fraser River sockeye will be discontinued as soon as analysis of the data on hand has been completed.

Dr. Rounsefell also carried on experiments in tagging in an effort to develop tags suitable for the salmon work. Experiments with rainbow trout showed that the usual strap tags on the tail or on the jaw were not satisfactory. The Atkins tag through the dorsal fin, however, was well retained and should be tried on a large scale with mature salmon. Its visibility is better than that of the strap tag, an especially valuable feature in searching for marked salmon on the spawning grounds.

A new type of tag was also developed and tried out on fingerling king and sockeye salmon. This mark, which was named the "internal anchor" tag, consists of three parts: an ordinary flat plate, similar in shape to the nickel herring tag, but preferably smaller; a second small plate of any desired shape, made out of bright-colored celluloid (except bright shades of red which are attacked by other fish); and a short piece of fine silver chain. The long flat plate is inserted into the body cavity with the chain (which is fastened to its center) protruding through the body wall; the second plate of bright-colored celluloid is fastened by one end to the free end of the chain.

In experiments with king salmon fingerlings there was a heavy loss from over-chlorinated city water but after 161 days the survivors were as follows: 36 percent of the controls, 10 percent of those marked with a large anchor and 20 percent of those marked with a small anchor. These fish were between 2 and 3 inches in length when tagged and the mortality was greater than would be expected from the tagging of slightly larger fish.

After 85 days the survivors of marked sockeye fingerlings are: Controls 100 percent, small anchors 91 percent, large anchors 90 percent, and medium anchors 100 percent.

Coho.—The coho salmon investigation of the causes of the decline in abundance of this important commercial and sport fish and of methods for rebuilding runs of former importance was continued during the past year by George B. Kelez.

During the winter and early spring, final returns from the first Samish River marking experiments [2] were obtained. The total return of 3-year fish from the two lots of hatchery-reared native stock, marked and released in 1934, was 469 fish. Of these, 7 recoveries were from 26,150 fingerlings, averaging 47.4 mm (approximately 1⅞ inches) in length, marked by excision of a pair of fins in May; and 462 were from an equal number of fingerlings, averaging 101.6 mm (approximately 4 inches) in length, marked by fin excision in November. The ratio of return of the large fingerlings to that of the small ones indicated a much higher survival rate due to the prolonged rearing period.

Final returns from 9,800 fingerlings, averaging 49.2 mm (approximately 2 inches) in length, transferred from the Skykomish River and marked and released in the Samish in 1934 were also obtained during this period. Recovery of a total of 11 fish was made from this experiment, a return considerably greater than that from the smaller native fish.

Marked fish returning from the experiments carried on in 1935 in Voight's Creek, a tributary of the Puyallup River were recovered during the late fall of 1937. Two lots of fingerlings had been marked by excision of different pairs of fins. The first of these consisted of 50,000 fish reared at the Puyallup River State hatchery, which averaged 49.7 mm in length at the time of marking, and the second consisted of 25,000 fingerlings, averaging 49.1 mm in length, transferred from the Green River State hatchery to the Puyallup River immediately before marking. With the run virtually complete, recoveries to date number 28 from the native stock and 8 from the transplanted stock. No recoveries have been made at the Green River hatchery.

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[2] See Progress in Biological Inquiries, 1934 and 1936.

A further series of experiments on coho fingerlings have been undertaken during the year to determine the effect of various periods of hatchery-rearing on the return at maturity. This work has been carried on at the Quilcene, Wash., station of the Division of Fish Culture. One lot of these fish was released in September and another in December in the Quilcene River immediately below the station. Additional lots of fingerlings from the same brood are being retained in the hatchery ponds for marking and release during the spring of 1938 at the approximate time of normal seaward migration. Exact costs of rearing and handling are being recorded in order that the comparative results of moderate and long rearing periods may be determined.

Because the number of individual lots of fish which can be marked by excision of a pair of fins is definitely limited by the number of possible combinations, an experiment was undertaken to determine the adaptability of the internal tag for this purpose. The use of these tags has heretofore been confined to relatively large fish and has been attended by the disadvantage that an external mark to indicate the presence of a tag is lacking. Both hatchery-reared and wild coho fingerlings, ranging in size from 43 to 80 mm were obtained and tagged with internal celluloid tags measuring 2 by 12.5 mm and of varying thicknesses. One fin was removed from each fish at the time of tagging and the various lots were held in aquaria for 75 days. Losses in the experimental lots ranged from mortality approximately equal to that of the controls to 75 percent greater than that of the controls.

An operation on a larger scale was then undertaken at the Samish River hatchery to test the tags under field conditions. Tags of 0.030 inch thickness were selected on the basis of the previous experiment and the dorsal fin was removed from each fish at the time of marking for external identification. Excessive losses from a fungus infection were encountered with the first lot marked, which was held in troughs inside the hatchery. After treatment with salt baths for some time the remaining fish were removed to an outside concrete pond, where they were held until there was no further daily loss.

Lots of these fish were released in Friday Creek on October 8, October 20, and December 11. If the results from tagging compare satisfactorily with those from fin marking, greater opportunity for comparative studies of individual lots of fish will be afforded.

Sampling of commercial and sport catches for data on size, sex, and age was continued and stream collections of fingerings were made for additional material on early life history and rate of growth of coho salmon. A comparison of scale samples from various points in Alaska with those from the local runs indicates that an increasing number of fish in northern waters are returning to spawn at the age of 4 years. All scales examined have shown only 1 year of residence in the ocean, the 4-year fish in Alaska having remained in fresh water until their third year.

Little increase in local spawning escapements has been noted in recent years and a considerable decrease in the commercial catch has been evident. Since local populations mature almost exclusively in the third year, the coming season should demonstrate the effect on this species of the removal of fixed fishing gear from these waters in 1935. Unless the beneficial results of this reduction in gear are considerably greater than is anticipated, more stringent measures for securing an adequate spawning reserve of this species must be adopted if a continued decline in numbers is to be avoided.

KARLUK RIVER RED SALMON

The investigation to determine the extent and causes of the fluctuations in the size of red salmon runs in Karluk River, Alaska, was continued in 1937 by J. T. Barnaby and A. C. DeLacy.

Operation of a counting weir in the river provides data on the number of adult fish escaping to the spawning grounds. This escapement, together with the daily catches of salmon made by the companies fishing in the Karluk district, is used to determine the total run into the river. The age group composition of the 1937 run was calculated from an analysis of 14,000 scale samples taken throughout the season. This study of the salmon populations spawning in Karluk River is furnishing valuable data on fluctuations in the size of the runs and also on variations in the ratio of return to escapement.

Studies of the relation between the growth rate of young salmon in fresh water and their survival both in the fresh water and in the sea were continued. Samples of seaward migrant young were collected for the purpose of determining the age and length frequencies of the 1937 population. Results thus far obtained from this study indicate a positive correlation between fresh water growth rate and survival.

During the season an examination of 434,000 adult salmon disclosed more than 2,100 marked individuals returning from previous years' marking experiments. The numbers and ages of these marked fish indicates that the mortality rate of salmon while in the ocean is fairly constant. The slight variations which occur in it from year to year are not of sufficient degree to account for the great variations in the total survival of these fish from one generation to another. It is evident that the wide fluctuations in the ratio of return to escapement are due primarily to variations in the natural conditions affecting survival in fresh water.

Studies of the food available for young salmon in fresh water entailed a chemical analysis of the waters of Karluk Lake and its tributary streams as well as the sampling of these waters for plankton content. The phosphorous, nitrate, silica, oxygen, and carbonate content of these waters was determined a number of times during the season. As noted in previous years, phosphorous and silica were the chief limiting factors in the growth of plankton and the associated growth of young salmon which depend upon the plankton for their food supply.

Predatory species.—The Dolly Varden trout is considered the chief predator of the salmon during their stay in fresh water. Although a considerable amount of money is expended every year by the Territory of Alaska and the various fishing companies in destroying this char, very little is known about the species. Dolly Varden trout inhabit the coastal streams on both sides of the Pacific from California to Alaska and south to Japan. Some spend their entire life in streams, some live entirely in lakes, while others spend part of their life in a stream or lake and part in the ocean. The mature fish vary in size from 6 to over 24 inches in length, depending on their habitat and the population pressure. They are frequently found with salmon eggs, fry, and fingerlings in their stomachs, and consequently their extermination is desired by most members of the salmon industry.

As these fish are very abundant on Kodiak Island and probably are detrimental there as well as elsewhere to the salmon population, a series of marking experiments were initiated during the past year to furnish some information on the migrations, age, and growth rate of this species. Some of the chars were marked by excising two of their fins; others by insertion of a numbered metal tag in the body cavity and excision of the adipose fin so that they could be easily identified when recaptured. Three experiments were started at Karluk and two at Red River, a stream entering Shelikof Straits about 35 miles south of Karluk. In the Karluk experiments chars were marked in the Karluk River during their migration to and from the ocean and in Karluk Lake. In the Red River experiments chars were marked during their upstream and downstream migration.

Fish from only the first experiment of each series (those on downstream migrants) have been recaptured to date, but recoveries will probably continue for 2 or 3 years. The information obtained from these experiments to date is as follows:

1. Of the chars marked at Karluk in June as they were migrating to the ocean, over 12 percent were recaptured between July 17 and September 9, while on their return migration upstream. Of the chars marked in the first Red River experiment 18 percent were recaptured between July 12 and August 18 as they were migrating upstream. Thus, an appreciable percentage of the chars which migrated to the ocean in the spring returned to their home-stream in the fall of the same year.

2. Marked chars from the Karluk experiments were recaptured in salmon traps in the vicinity of Uganik Island over 45 miles away from the point of tagging and marked chars from the Red River experiments were recaptured in Uyak Bay over 60 miles from the point of tagging. These data show that after entering the ocean some of the chars wander a considerable distance away from their home stream.

3. That some straying of chars from one stream to another occurs was proven by the recovery of Karluk marked fish at Red River (5 percent of the total recoveries) and Red River marked fish at Karluk (0.6 percent of the total recoveries). Because of differences in fishing regulations, the difference in the amount of straying may not be as great as the figures indicate. Fishing operations are carried on as close to the Karluk River as 100 yards, whereas fishing is prohibited within 1 mile of Red River.

4. These fish grow very slowly during the time spent in the ocean. Although many of the Karluk and Red River chars attain the same length as red salmon, the latter, when in the ocean, grow approximately 6 centimeters (2⅜ inches) a month during June, July, and August,

while data obtained from the marking experiments indicate that the chars grow only about one centimeter a month during this period. Hence, it appears that these fish have a relatively long life span, a supposition which is, in a measure, confirmed by the otolith readings.

Both scales and otoliths have been examined and it has been found that the scales are virtually useless as a means of age determination, and that the otoliths, while of some value, are not altogether satisfactory. This difficulty makes the study of the life history much more complicated and other methods of age determination are being tried.

At Karluk Lake it was noted that chars take a very heavy toll of red salmon fry in the spring at the time the young fish are entering the lake from the spawning streams. However, during the summer and fall relatively little damage is done to the salmon populations by these chars. They have been caught by means of seines and gill nets, and only rarely was one found that had been feeding on salmon fingerlings. Although salmon eggs do comprise a large part of the diet of these fish, it was noted that the chars were feeding almost entirely on floating eggs displaced by the spawning activities of the salmon and these eggs would die whether they were eaten or not. An analysis of stomach contents of chars in Karluk River showed that the chars in the river were not feeding on seaward migrants.

PINK SALMON

The pink salmon investigation in southeastern Alaska was continued in 1937 by Dr. F. A. Davidson and Samuel J. Hutchinson. The investigation, as in the past, covered numerous pink salmon research problems. Activities were about equally divided between the summer field work in Alaska and the compilation of scientific data at the laboratory in Seattle. The summer field station at Little Port Walter, Alaska, was operated for its fourth consecutive year, remaining in active operation throughout the summer from May 20 to September 20.

The runs of pink salmon in southeastern Alaska during the 1937 season were comparatively light in practically all districts. The total pack of canned salmon was below average but the proportionate take of the total population was as great, if not greater, than in previous years. Catch statistics and studies of escapements into the streams for each district show that in the majority of cases the spawners were insufficient in number to make adequate use of all the available spawning ground afforded throughout the region. In 1937, the rainfall was in excess and most streams provided suitable water conditions for that portion of the population that successfully escaped the intensive commercial fishery.

All through Alaska the trend is toward cannery modernization and increased capacity. As a result the amount of fishing gear is expanding in an effort to increase the take of raw material. It is clear that the saturation point has been reached in all districts in southeastern Alaska and that the industry must, to maintain itself, be content with a smaller average pack per plant if it is to continue in the future. The problem facing the production of salmon in Alaska is nothing more than a farming problem. Seed must be planted if a crop is to be produced, and part of the crop produced must be conserved for seed. The spawning grounds are of limited size, tending to decrease rather than increase, thus making it impractical to think of the salmon resources as an ever increasing commodity.

No tagging experiments were conducted in southeastern Alaska during the summer of 1937, owing to the lack of suitable equipment and funds. The returns from the 1935 and 1936 taggings were studied and a detailed report has been submitted showing the migration routes of pink salmon through Clarence Strait and adjoining waters. It is shown that fish tagged at various time intervals during the spawning migration are bound for widely separated areas. Knowledge of this change in migration as the season progresses provides an explanation of the seasonal shift in the fishery and therefore aids in the establishment of the various boundaries for each district. This tagging report covers both the odd and even year groups and indicates the peculiar migration characteristics of each population.

Weir counts taken at Little Port Walter this year gave the second set of returns from a known even-year escapement and the first returns from a known odd-year escapement. A total of 7,085 pink salmon from the 1935 spawning population were counted through the weir from August 16 to September 10. Previous weir count totals consisted of 6,952 pink salmon in 1934, 6,073 in 1935, 5,164 in 1936, and 7,085 in 1937. The 1937 escapement is a 17 percent increase over the 1935 spawning population, while the 1936 returns were a 26 percent decrease under the 1934 population. Causes for such fluctuations can only be determined through a study of natural and imposed mortality from one point in the life cycle to the corresponding point in the life cycle of the following generation.

The sex of the individuals composing the run was determined as the salmon passed through the weir. This was accomplished with the aid of a specially constructed pen just above the counting gate which enables the observer to determine and record the sex of the individual fish as they pass through. In this stream males predominate at the beginning of the season, the ratio in some days running as high as 90 percent. This excess of males continues until the run is about three-fourths complete at which time the ratio stands at 2 to 1. During the last quarter of the run the females increase in abundance to such an extent that the ratio of sexes for the season as a whole is balanced. Factors influencing sexual development were observed throughout the season and actual weights of the gonads were taken at various intervals to determine percentage change in weight of sexual products over body weight.

Egg counts were taken to determine the average egg deposition that could be expected for the 1937 run. The average number of eggs produced per female in 1937 was 2,059, which resulted in the deposition of approximately 7,293,000 eggs in the gravel beds of the stream.

Three samples of the run were taken during the season for racial analysis measurements. From 26 body measurements taken from each individual a number of comparisons are made to determine the significance of individual variation. The continuation of racial analysis is expected to provide a method of segregation of various populations which will aid in formulating regulatory measures for future conservation.

Cooperative work with the National Canners Association of Seattle, Wash., carried on for the third consecutive season at the station, consisted of a study of the physical and chemical changes occurring in the pink salmon run at Little Port Walter. Daily samples of pink salmon taken from the experimental trap in the bay were weighed, measured, and a proportional cut from each fish was canned. The canned samples have been turned over to the National Canners' Association for tests to determine the chemical changes that take place as the season progresses and as the salmon near sexual maturity.

A cooperative observer's meteorological record was maintained at Little Port Walter to secure information on a number of weather conditions that are important elements in the salmon's environment. A monthly average of 18.16 inches of rain fell at Little Port Walter during 1937, making a total of 217.90 inches for the year. Rain was recorded on 248 days. It is not known whether this is an excess as the weather station has only been in operation for the past year and a half. The highest air temperature for the year was 72° F., and the lowest was 16° F., with a yearly mean average of 42.73° F., 58 clear days, 94 partly cloudy, and 213 cloudy days were noted at the station during the past year.

A paper, "The Geographic Distribution and Environmental Limitations of the Pacific Salmon," embodying discussions of factors coincident with the native and foreign distribution of the Pacific salmon was completed and submitted for publication. In every instance where transplantations have been successful the conditions throughout the new habitat have been similar to those in the native waters, thus indicating that a thorough knowledge of the environmental conditions of a proposed habitat is essential before transplantations of the Pacific salmon into foreign waters are attempted.

ALASKA SALMON STATISTICS

Collection and compilation of daily catch records from the various types of fishing gear operated by the salmon fishery in Alaska was continued in 1937 by L. S. Christey. With the continued assistance of a W. P. A. project initiated in 1936, a complete collection of all available catch records for the remaining fishing districts in Alaska has been accomplished. Along with past records all current records are collected and the files will be kept up to date in the future.

Compilation of these data consists mainly in determining average daily catches for each type of gear throughout each fishing season. This information gives an insight into the relative abundance of salmon in each of the fishing districts and any change which occurs in the date of appearance of the runs of salmon. During the past year the trap-catch records in both Prince William Sound and southeastern Alaska were compiled for all years on this basis. This information as in the past was used as a basis for recommending changes in the fishing regulations in Alaska in order to provide for the conservation of the salmon resources.

HERRING

Investigation of the herring fisheries of Alaska was continued in 1937 by E. H. Dahlgren. A temporary assistant was assigned to the recently expanded Prince William Sound and Kodiak districts during the fishing season to obtain data on the size and age composition of the runs in these areas and to bring up to date the statistics of these now important fisheries.

Continuing the migration studies, tagging was again carried on during the spring at the Sitka and Craig spawning areas, which are known to contribute the greatest supply of herring to the commercial catch. In this experiment approximately 14,000 individuals were marked at Sitka and 11,000 at Craig. The electronic detector was again operated in Southeastern Alaska for the recovery of tagged individuals and 113 recoveries were made during the season.

From these recoveries, together with others made in previous years, the migration habits of the commercially important populations have been established. It is evident that: (1) the fishery in the Cape Ommaney area, from which 60 to 95 percent of the total catch is made, draws almost exclusively from the population which spawns in the vicinity of Sitka; (2) the Warren Island fishery draws from an intermixture of the Craig and the Sitka populations, and a small influx of herring from minor spawning grounds south of Craig at least as far as Rose Inlet, approximately 40 miles south of the major spawning area; (3) the summer fishery conducted on the west coast of Kuiu Island, including Malmesbury, Tebenkof, and Pillar Bays, is composed, as is the Warren Island fishery, of herring from the Craig and Sitka spawning areas; (4) the Douglas Island fishery is supported by the Juneau spawning populations; and (5) the Icy Strait and Tenakee fisheries are composed of an intermixture of Juneau fish with some unknown population, most probably that of the Kootznahoo spawning area.

The herring in the Cape Ommaney fishing area from which the bulk of the commercial catch in southeastern Alaska is made, have shown a marked decline in abundance during the past few years. The measure used in evaluating this abundance is derived by a comparison of the catch per unit of gear per day's fishing with the average catch per day's fishing established over a 9-year period. In deriving these indices, the fleet has been divided into two groups (those of over 35 net tonnage capacity and those under this size) to minimize the effect of the difference in efficiency of the larger and smaller vessels.

The index for the 1937 season for the larger vessels was 71 compared with 73 for the 1936 season, 140 for the optimum year of 1932, and 62 for the minimum year of 1935. The indices for the vessels not over 35 net tons for 1937 was 75, compared with 60 for the minimum year of 1936 and 164 for the optimum year of 1932.

This continuing low level of abundance, while doubtless due in large measure to an overly intensive fishery, was brought about in part by the virtual failure of the three successive spawnings of 1932, 1933, and 1934, to contribute the normal increment of young fish to the populations. The entrance during the 1937 season of a large percentage of the new age class resulting from the more successful spawning of 1935 may be expected to result in a rise in the level of abundance. This year class, which appeared in large numbers as 2-year-olds in the 1937 catch, may be expected to contribute a large portion of the catch as 3-year-olds during the coming season.

The low catch per unit of gear in the Ommaney area during the 1937 season was due in part, also, to the emigration out of that area of the age group which had supported the fishery during the three previous years, the abundant 1931 year-class. Tagged individuals belonging to this age-class were taken in large numbers in the Tebenkof-Pillar Bay area on the west coast of Kuiu Island, increasing the catch in that area, but causing a lower catch in the Cape Ommaney region. Such differential schooling has been observed before, especially when, owing to the failure of a series of spawnings, the population is composed of age groups of marked size difference.

The fishery in the Kodiak area, originally developed for the curing of herring, was expanded in 1935 to one for reduction. With this change in the method of utilization there followed a change in the type and intensity of fishing activity—a change which has resulted in a tremendous increase in the poundage taken from this area. A similar change has occurred in the Prince William Sound district, although the shift from curing to reduction has been more gradual. Owing to limited personnel, adequate collection of data from these areas has lapsed during the past few years. With the rapid expansion of the fishery, however, it was deemed essential that records of the catch and of the size and age composition of the catch again be collected in order that signs of depletion might be detected before the fishery declines to the point of commercial extinction, as it did in these areas in early years.

PACIFIC PILCHARD INVESTIGATIONS

O. E. SETTE, *in charge*

From relative insignificance in pre-war years, the fishery for the Pacific pilchard, also known as California sardine, (*Sardinops caerulea*) has grown to enormous proportions, a total catch of over 750,000 tons being landed in the season of 1936–37. This is a quantity three times as great as the annual landings of all other kinds of fish in the Pacific Coast States. Attending the expansion of this fishery has been the growth of public concern over the ability of the resource to provide such large catches without endangering the future supply. In California, where most of the catch is taken, this concern has been felt for a number of years and has been expressed in State regulations placing certain restrictions on the use of this fish for reduction to meal and oil. In offshore waters, beyond the 3-mile limit, floating reduction ships have operated without restrictions—a condition considered intolerable by shore operators and State authorities.

The seeking of Federal legislation intended to place the offshore operations under State jurisdiction brought Federal attention to the controversial situation in California. At the same time the legislatures of Washington and Oregon petitioned Congress for a Federal scientific investigation of the pilchard resource which was being fished with increasing vigor in the waters off their shores. As a result, the appropriations of the U. S. Bureau of Fisheries were increased to provide for a Pacific pilchard investigation. The funds became available July 1, 1937, and before the end of the year a staff headed by Oscar E. Sette was detailed to the investigation. The kindness of Stanford University in providing generous laboratory space has led to the establishment of headquarters at a point centrally located with respect to the fishery. Since this investigation lies in a field in which the several States, notably California, are conducting important research, their cooperation in formulating a program and in furnishing data has been of great value.

The first months of the investigation have been devoted to a preliminary reconnaissance of the problem. The basic questions are: (1) Do the fisheries of various localities draw upon one population or upon several self-perpetuating populations? (2) What intensity of fishing will provide the maximum yield of fish of greatest commercial value from each successful year-class? (3) What intensity of fishing will permit survival of a spawning stock adequate to produce successful year-classes?

The first question is being investigated by California, Oregon, Washington, and British Columbia, by the tagging method. It has already been proven that some individuals migrate long distances from Southern California to Washington and vice versa. Whether this represents a small percentage of mixing of the population along the entire coast remains to be seen. It is planned to study this aspect of the problem by discovering to what extent the young as well as the adults occur in the north and to make comparisons of morphological characters to see whether there are any distinguishing features between northern and southern pilchards.

The second and third questions are more perplexing and their answers more remote because they involve determination of age and of abundance. Satisfactory techniques have not yet been developed for either of these determinations. Accordingly work has started on developing a technique of age determination by interpreting age marks in hard structures, by observing modal progression in sizes of young pilchards, and by identifying modes in frequency distributions of the adult population; and on developing a technique of estimating abundance from catch statistics and by aerial observation of schools, or by a combination of the two methods.

Progress in the solution of these problems will be accelerated by cooperation with State fishery research units which have collected and kindly made available many pertinent data. A series of measurements based on samples collected from the commercial catch over a period of years by the California State Fisheries Laboratory is expected to be particularly useful in this connection.

Although the discovery of techniques of age and abundance determinations are prime essentials and will greatly advance the understanding of conservation problems, it must be pointed out that preservation of an adequate spawning reserve will require a quantitative determination of annual egg production in all potential spawning areas. This cannot be undertaken until a seagoing vessel is available to make periodic surveys in cooperation with such boats as the States have available for this purpose.

GREAT LAKES FISHERY INVESTIGATIONS

Dr. John Van Oosten, *in charge*

The limited amount of field work conducted during 1937, permitted the Great Lakes staff to continue the compilation of extensive data collected in earlier years. In addition to the papers published by staff members during the year, several other manuscripts were prepared for publication. Among these was a report setting forth the results of an intensive study of the whitefish fishery of Lakes Huron and Michigan. This investigation was concerned especially with the effects of the deep trap net fishery on the abundance of whitefish in these two lakes.

Two important forward steps were made in Great Lakes fisheries administration during 1937. First, the adoption by Wisconsin, Illinois, Michigan, Ohio, and the Province of Ontario of the flexible rule method of measuring gill net meshes brought a troublesome problem to a satisfactory conclusion. The flexible rule provides an extremely accurate and impersonal method of determining the legality of gill net meshes. Earlier methods of gauging gill net twine were open to the criticism that the results obtained varied according to the procedure followed by the individual making the measurements. The second important advance in Great Lakes fishery administration was the passage of the "discretionary power" act by the Wisconsin Legislature. This law empowers the State conservation officials, after consultation with and on the advice of commercial fishermen, to enact commercial fisheries regulations by decree. As a result the conservation officials can meet emergency situations readily and are also in position to frame a rational long-time program for the rehabilitation of Wisconson's sadly depleted fisheries.

No significant advance can be claimed in the fundamental problem of obtaining uniform regulations for Great Lakes fisheries, nor does there appear to be much likelihood that adequate and uniform regulations can ever be attained through the medium of interstate agreement. The growing realization that satisfactory fisheries regulations cannot be attained by the united action of the States is reflected in a rising sentiment for the regulation of Great Lakes commercial fisheries by a Federal or international agency.

Active cooperation continued to mark the relationship of the Great Lakes staff with the State officials and with the fishing industry. Cooperative projects requiring field work were the gill net investigations on Lake Erie, the study of the effect of commercial fishing on the game fish in Potagannissing Bay, Lake Huron, and the general survey of the relationships between sport and commercial fishing in southern Lake Superior and northern Lakes Huron and Michigan. Dr. Van Oosten again issued numerous memoranda relative to Great Lakes fisheries problems, and on several occasions at the request of State officials aided in the framing of commercial fisheries regulations.

The Bureau is greatly indebted to the University of Michigan for laboratory space, and for numerous other accommodations and courtesies extended to the staff.

FISHERY STATISTICS

A complete analysis, by methods outlined in previous reports, was made of the 1936 statistics of the commercial fisheries of Great Lakes waters under the jurisdiction of the State of Michigan. There are now available detailed records of fluctuations in fishing intensity and in the production and abundance of the important commercial species over an 8-year period (1929–1936) for each of the 22 fishing areas or statistical districts into which the State of Michigan waters have been divided. The statistical data on the whitefish in Lakes Huron and Michigan proved of great value in the study of the whitefish fisheries of these lakes completed by staff members during the year.

AGE AND GROWTH STUDIES

Lake Erie sheepshead.—An investigation of the Lake Erie sheepshead (*Aplodinotus grunniens*) by Dr. Van Oosten included data on growth rate, growth compensation, the age and year-class composition of the stock, the relationship of total and standard length, the length-weight relationship, and the coefficient of condition. Although one fish in its thirteenth year and another in at least its seventeenth year (this latter fish was 27.2 inches long) were found, the bulk of the collection was made up of young fish. The dominant age-group was the I-group (1926 year-class) with an average length of 8.6 inches.

Other facts brought out were: growth compensation occurs in the sheepshead; the ratio, standard length in total length, decreases with growth; the coefficient of condition increases with age but is not correlated with growth rate.

Lake Erie yellow perch.—The investigation of the life history of the yellow perch (*Perca flavescens*) of Lake Erie, suspended in 1935, was resumed in August 1937, upon the return of Frank W. Jobes to the Great Lakes staff. The preparation of a manuscript dealing with the age and growth of the yellow perch in Lake Erie is now under way. The comparison of the growth of the sexes in the yellow perch reveals an unusual situation. In the first year of life the males grow more rapidly than the females, but in all later years the females have the better growth.

An integral part of the growth study is the examination of the body-scale relationship as determined from measurements of selected or "key" scales. From the preliminary tabulation of the material it appears doubtful whether any simple mathematical formula can be employed in the calculation of the growth of the Lake Erie yellow perch. The use of a purely empirical curve of the body-scale relationship may prove necessary.

The coefficient of condition was found to vary according to locality and season. Sex differences occur only in the spawning season at which time the females have distinctly the higher coefficient. The study of season variation revealed that condition is best during the summer.

Lake Erie whitefish.—After a lapse of several years the study of the Lake Erie whitefish (*Coregonus clupeaformis*) has been resumed. All scales have now been read and measured, and the individual growth histories calculated. Data relative to the various phases of the life history of the Lake Erie whitefish have been compiled in tabular form preparatory to writing a report on this subject.

FOOD OF LAKE MICHIGAN LAKE TROUT AND LAWYERS

A report on the quantitative and qualitative analysis of the contents of 4,979 lake trout (*Cristivomer namaycush*) stomachs and of 1,528 lawyer (*Lota maculosa*) stomachs was completed by Drs. Van Ooosten and H. J. Deason. The food of the trout consisted of 98 percent by volume of fish of which Cottidae and Coregonidae were the principal constituents. Cottidae were dominant in southern Lake Michigan (72 percent by volume), Coregonidae in northern Lake Michigan (51 percent), but the lake shiner (*Notropis atherinoides*) was most important in Green Bay in the spring of the year (64 percent). The lawyer food consisted of 74 percent by volume of fish and 26 percent invertebrates. Dominant items were Cottidae (76 percent by volume) in southern Lake Michigan, Coregonidae (51 percent) and *Pontoporeia* (37 percent) in northern Lake Michigan, and *Percopsis* (34 percent) and *Mysis* (26 percent) in Green Bay. Data were also obtained on the frequency of occurrence of the food items, variation of food with the size of the predator, depth of water, season, and locality; on the number of individual fish of each species destroyed by trout and lawyers; and on the calculated volume of food preceding digestion. The lake trout and lawyers are competitors for the same food, and are both predators of the commercially important Coregonidae. The lawyer through its consumption of invertebrates is also a food competitor of the Coregonidae.

The large number of Cottidae secured from the lake trout and lawyer stomachs made possible a report on the distribution of three species, *Cottus cognatus*, *Cottus ricei*, and *Triglopsis thompsonii* in Lake Michigan. The number of records previously published from Lake Michigan was surprisingly small because these species are only rarely taken by commercial fishing gear.

SPECIAL SURVEYS

Potagannissing Bay Investigation.—The repeated insistence by sport fishing interests that commercial fishing operations should be prohibited in the Potagannissing Bay area of northern Lake Huron in order to protect game fish led to the passage of a resolution by the Michigan State Senate requesting the Michigan Conservation Commission and a representative of the United States Bureau of Fisheries to conduct an exhaustive survey of the fishery conditions in that region. A preliminary survey was made by Dr. Van Oosten and Fred Westerman of the Michigan Conservation Department from May 28 to June 2. A program of weekly sampling was instituted and was carried on by conservation officers, to determine the species composition of commercial trap net catches and particularly to ascertain how extensively game fish, especially black bass, occur in these nets. Subsequent visits to check the progress of the investigation and to amend the program were made by Bureau representatives during the periods from July 16 to 21 and August 6 to 10. The investigation will be continued throughout the winter season. Following an analysis of the data, recommendations for the regulation of the fisheries of the area will be formulated.

Lake Erie gill net investigation.—In August 1936, the gill net fishermen operating in the State of Ohio waters of Lake Erie secured a court injunction which restrained the Conservation Department from enforcing the law regulating the size of mesh in small-mesh nets. The fishermen held that their admittedly illegal nets were not catching more illegal fish than the 10 percent permitted by law. At the request of the Ohio Conservation Department and the Ohio Gill Netters Association an agreement was made on March 31, 1937, that provided for an investigation by the United States Bureau of Fisheries. Dr. Deason was in the field from April 7 to May 6 and from October 21 to November 6 collecting data on the relationship of the size of blue pike-perch, yellow perch, and saugers and the volume of the catch to the size of the net mesh. The mesh sizes of the nets studied ranged from 2⅝ to 2¹⁵⁄₁₆ inches. On the basis of the 1937 and earlier (1927–28) gill net studies, the Bureau will recommend a definite mesh size for gill nets used for all species commonly taken in small-meshed nets, and will recommend also an upward revision of the present legal size limits for blue pike-perch and saugers in order to provide better protection for spawning females. It is not anticipated that the recommendations will differ materially from those made by the Bureau at an earlier date.

Another phase of the gill net investigations was the experimental study of the shrinkage of gill net twine. The adoption of the flexible steel rule, developed by the National Bureau of Standards, and the further legal provision that net mesh must measure full size at all times, whether new or old, wet or dry, caused considerable controversy over the allowance which should be made for shrinkage in ordering new netting. At the request of the fishermen, who provided the necessary materials, experiments are being conducted to determine the maximum shrinkage, rate of shrinkage, and the relative importance of water and of several preservatives in inducing shrinkage.

The differences among various methods of measuring gill-net meshes (stretched measure, 1 pound strain on 1 mesh, 1 pound strain on 3 meshes, 8 ounce strain on 1 mesh, and National Bureau of Standards flexible rule) are being determined experimentally. This information will be submitted to the fishermen and conservation officials of those Great Lakes States that have recently adopted the flexible rule as the legal method for determining the size of gill nets.

SHELLFISH INVESTIGATIONS

Dr. Paul S. Galtsoff, *in charge*

Oyster fishing continues to occupy a prominent position among the fishery industries of the country in spite of serious handicaps caused by the ever increasing depletion of natural oyster beds, destruction of valuable oyster bottoms by pollution, and depredations by natural enemies of the oyster. Dissemination of knowledge regarding the life history of the oyster has resulted in wider recognition of the fact that a system of oyster cultivation is necessary for maintaining the productivity of present resources.

Since success in the cultivation of oysters depends on knowledge of local conditions and good judgment in applying to them the basic principles of oyster culture, the shellfish investigations of the Bureau of Fisheries are conducted along the following lines: physiological studies, dealing primarily with the propagation and nutrition of oysters; ecological investigations, which provide answers to questions regarding the suitability of various waters to oyster culture; protection of oyster bottoms against starfish and other enemies; and investigations of the effect of trade wastes on oyster bottoms.

The first line of attack supplies the basic knowledge concerning the requirements and activities of the oyster which is essential for the practical oyster grower. Ecological observations made in 1937 in Long Island Sound and in the inshore waters of Virginia, North Carolina, Alabama, and Florida have been of great value to State authorities and private oyster organizations in transplanting seed and planting shells. Studies in the life history and distribution of the starfish disclose the inadequacy of present methods of control and demonstrate that in Long Island Sound control is an interstate problem. Experiments with the use of chemicals in the eradication of starfish are very promising and indicate that chemical control may soon be put on a practical basis. The work on pulp mill pollution provides convincing evidence of the toxicity of pulp mill effluent with the result that practical steps are being undertaken by interested parties to abate this hazard.

PHYSIOLOGY OF THE OYSTER

Physiological investigations on the oyster were carried out by Dr. Galtsoff and staff at the Woods Hole, Mass., laboratory. Studies were continued on sex changes in adult oysters, accumulation and storage of iron in oyster tissues, and the effect of industrial pollution on respiration.

Sex changes.—The work on sex change was undertaken with the view of obtaining additional evidence of sex reversal in adult oysters. Methods used by previous investigators are open to criticism. The method of comparing sex ratios of oyster populations is obviously inadequate where both types of change—from male to female and from female to male—are involved. The method of examining the gonads of living mollusks through holes bored in the shell is objectionable because of the unknown effect of injury on the presumably unstable gonad of the mollusk.

The method used in this investigation consisted in determining the sex of the oyster by inducing ovulation or ejaculation by increased temperature and chemical stimulation (Galtsoff, 1930, Proc. Nat. Acad. Sci., 16, No. 9, pp. 555–559). Of each of the 202 adult oysters tested at Woods Hole during the summer of 1936 an individual record of the spawning reaction was obtained and the discharged products were examined under a microscope. Each oyster was then measured and marked by engraving a number on its right shell. Elaborate precautions were taken to avoid any possibility of mismarking. Oysters were then transferred to Milford, Conn., where they were kept in large tidal tanks.

During the summer of 1937, the sex of these marked oysters was redetermined by the same method used in 1936. It was found that 9.7 percent of the oysters had reversed their sex. The percentage of reversals was considerably higher among females (13.1 percent) than among males (8.0 percent). The mortality during the year was only 7.04 percent, probably a normal death rate among adult oysters.

As previous observations by Dr. Galtsoff have shown, ovulation of the female is accompanied by typical rhythmical contractions of the adductor muscle and passage of eggs through the gills, while in the male ejaculation proceeds through the cloaca and does not involve specific behavior of the adductor. In the sex reversed males the physiological set-up of the organism changes with the change of sex and a typical female reaction develops. In several instances, however, the development of this reaction lagged, the newly formed female still acting as a male by discharging eggs through the cloaca and failing to develop rhythmical contractions of the adductor. Its kymograph record could easily have been mistaken for a male reaction. A month later a typical female reaction was fully established. Another sex reversed male had a fully developed muscular reaction but the discharge of eggs continued through the cloaca, indicating a deficiency in the mechanism which forces eggs through the gills. All sex reversed females reacted as true males. From these observations the conclusion is reached that the female reaction has developed as a secondary adaptation which provides a mechanism for the dispersal of eggs through the water. The male reaction is regarded as a primary sex reaction of the oyster.

A hermaphroditic oyster found among a group of new oysters tested during the summer had an atypical reaction possessing the characteristics of both sexes. This oyster discharged both eggs and sperm and was capable of self fertilization.

Present observations which establish a sex reversal in adult oysters occurring simultaneously in both sexes can be explained by assuming that the changes of the fundamentally bisexual gonad of *Ostrea virginica* are controlled by some hormonic system in which the development of one sex or another is inhibited. Whether these changes are hereditary characters which occur only in a certain group of individuals remains to be demonstrated by further observations. Since abnormal sex ratios have been observed in adult oysters grown on natural bottoms, understanding of the factors controlling the change of sex is of obvious practical significance to breeders and may be valuable for the maintenance of spawning grounds.

Accumulation and storage of iron.—The possibility of increasing the iron content of oysters by keeping them in water to which iron oxide was added was demonstrated in a series of experiments conducted in the laboratory at Woods Hole and in tidal tanks at Milford. In the latter place iron was added to sea water by suspending several pounds of nails in bags. There was considerable discoloration of the water due to the presence of suspended particles of iron hydroxide, but there was no material increase in the amount of iron in solution. In several instances upon the addition of iron oxide the amount of iron in solution even decreased. The accumulation of iron in the tissues of the oyster gradually increased, however, rising during a 6-month period from about 150 mg to more than 1,000 mg of iron per kilo of dry meat. Histological analyses proved that iron oxide particles are absorbed by the blood cells of the gills and are carried away and stored in the mantle and in the anterior part of the body.

Effect of industrial pollution on respiration.—Suspecting that phenol salts may be the toxic substances of pulp mill waste which affect the oysters, a study was made of the effect of pure phenol on respiration. Using the technique developed in previous years the oxygen consumption of the oyster was measured under normal conditions and in water containing phenol in concentrations 1:20,000; 1:1,000 and 1:500. The results show no significant changes in the rate of respiration in the presence of this substance.

OYSTER CULTURAL STUDIES

Prediction of spawning and setting in Long Island Sound.—The development of methods for accurately predicting the time and intensity of setting of oysters in Long Island Sound was one of the principal investigations carried out at the Milford, Conn., laboratory by Dr. V. L. Loosanoff and James B. Engle. To obtain a broader knowledge of conditions governing the survival of oysters in the Sound and its tributaries, a study of the physical and biological factors was undertaken on a much larger scale than had been carried out during previous years.

For observations on temperature, salinity, conditions of oyster gonads, presence of larvae in the water and their setting at various depths, 23 stations were established in Long Island Sound proper from a point opposite the mouth of Saugatuck River in the west to Joshua Point in the east. All these stations were visited every week during the spawning and setting season.

Regardless of the fact that much work on the biology of the oyster has been carried on in local waters, no attempt has ever been made to conduct a systematic study of oyster setting in Long Island Sound proper. To fill this gap it was decided to determine the beginning and end of the setting period, the intensity of setting throughout this period, the intensity in relation to depth, the correlation between setting and the temperatures and salinity of water, and finally, the rate of survival of recently set oysters in different parts and in different depths of Long Island Sound. For these studies two oyster-seed producing areas located about 5 miles apart were chosen. The so-called Stratford Point area represented the natural oyster beds where little or no cultivation of oysters is carried on. Welch's Point area, on the other hand, was located in the center of cultivated grounds. In the studies of setting in each area, wire bag collectors of uniform size and containing approximately the same number of shells were used. The bags were removed from the water at semiweekly intervals and replaced by unused duplicates.

From the analysis of this year's observations as well as from the information already in the files of the station it may be concluded that the salinity of bottom water, which is subject to only slight seasonal changes throughout the year and remains virtually the same from year to year, is not a factor responsible for the success or failure of spawning and setting of oysters in the Sound. It was also noted that during the summer of 1937 spawning occurred at a temperature of less than 20.0° C. (68° F.) which had been regarded previously as the minimum temperature required to induce this act under natural conditions. The first and general spawning of oysters in the Sound took place on July 2 and 3. It was followed by a setting which was first recorded on July 17. Subsequent heavy settings in July and early August continued without interruption for 3 weeks. The last and rather light setting occurred on September 20. Examinations of spat collectors disclosed that setting took place from mean low water to a depth of 70 feet, but was heavier in shallow water. The first set in some places amounted to 10,000 spat per bushel, but mortality caused by attacks of starfish and drills ranged from 93 to 100 percent.

To assist the oyster growers of Long Island Sound in obtaining the best set, information accumulated by the laboratory staff was summarized and issued in weekly bulletins which were distributed through the cooperation of the Connecticut Shellfisheries Commission. The bulletins contained statements regarding the condition of oysters, changes in water temperature, and expected time of spawning and setting. A large number of oystermen availed themselves of the opportunity to obtain these data and used them to advantage by planting shells at the proper time and place. It is planned to continue this practice and if possible to extend it to a larger area.

Control of starfish.—Observations on propagation and feeding of starfish in Long Island Sound were continued. The fact that starfish were responsible for the destruction of the greater part of the early oyster set in the summer of 1937 clearly demonstrates the importance of these studies for their control. It was found that starfish spawned on or about June 15 at a temperature of 15.0° C. (59° F.). Setting began on July 7–8, and continued until September 20. The heaviest setting occurred from the middle of July until the middle of August. As in the case of the oyster spat, the newly set starfish were more abundant in shallow water although setting took place at all the depths from low water mark to 70 feet.

Experiments on chemotropism of starfish were concluded in the fall of 1937. These experiments sustained the conclusions arrived at in 1936, when the largest part of the experimental work was done, that the chemical sense of starfish is poorly developed. Usually a starfish does not detect the presence of food until it comes in actual contact with it.

It has been the general practice of oystermen to use boiling water or steam to kill starfish brought up by mops, an expensive procedure because of the large quantities of fuel used to maintain water at the boiling point. In the belief that water of much lower temperature would kill starfish, a series of experiments was undertaken to determine the minimum lethal temperature for these animals. It was found that a temperature of 50° C. (122° F.) was sufficient to kill the starfish and that the use of boiling water is therefore unnecessary.

Although it is well known that starfish do not occur in water of low salinity, the limits of tolerance for this species have not been determined with accuracy. Experiments undertaken to provide this information disclosed considerable individual variations in the ability of starfish to withstand brackish water. When subjected to a salinity of 14.00 parts per thousand some of the starfish died in 3 days while others survived 13 days. The limit of tolerance is probably around 16.00 parts per thousand, for in this dilution of sea water some animals were kept alive 2 months.

At the request of Virginia oystermen a survey of the distribution and abundance of starfish in the lower Chesapeake Bay was made in March. The investigation revealed that starfish were confined to the area south of a line drawn from New Point Comfort to Cherrystone Island. The largest concentration was found near York Spit Light. Other areas of heavy infestation were found 3 miles southeast from Back River, 3 miles north of Little Creek, and in the vicinity of Old Plantation Light. The starfish population was not uniformly distributed, being on muddy bottoms where there was an abundant supply of small clams, *Mulinia lateralis*, upon which they were feeding. No starfish were found on oyster bottoms located in the areas of low salinity. In April, with the rise of water in the rivers emptying into the Chesapeake Bay, the starfish population withdrew toward the mouth of the Bay.

Effect of pulp mill pollution on oysters.—At Yorktown, Va., Dr. Walter A. Chipman, R. O. Smith, and L. L. Garriss were engaged in investigating the cause of the decline in oyster production in the York River. Studies of the effects of pulp mill pollution on oysters are an important part of this investigation.

Confirming the results obtained in 1935 and 1936, observations made during this year showed that oysters in the York River below Claybank were healthy and marketable, while those above that point were extremely poor and unfit for market. The shells of the upper York River oysters are much thinner than those of the lower York River oysters and the meats are much more watery. The oysters of the Piankatank River which are studied for purposes of comparison were found to be in excellent condition. Chemical tests of the glycogen content bear out the observational data. During the year the fluctuations in the glycogen content of the three groups of oysters were as follows: Upper York River, 1.65–1.88 percent; Lower York River, 2.65–5.28 percent; Upper Piankatank River, 2.97–5.44 percent.

Remarkable improvement was found in the condition of oysters transplanted from beds in the upper York River to other localities. The shells were strengthened by deposition of lime, the meats "fattened," and the green color of the meats had disappeared.

Additional samples of oysters were taken this year from various parts of the York and Piankatank Rivers and from other areas throughout the lower part of Chesapeake Bay for a study of the distribution of *Nematopsis*, a gregarine parasite known to infest oyster tissues. It was found that the parasite infestation was quite general and that oysters from many areas containing good marketable oysters were infested, indicating that the poor condition of the upper York River oysters could not be attributed solely to parasite infestation.

The hydrographical conditions of the York and Piankatank Rivers were observed regularly throughout the year following the same general program described in Progress in Biological Inquiries for 1936. Measurement of current velocities and of the tide in the upper York River was completed. Analysis of the completed data indicates that there is little nontidal current (average 0.04 knot downstream) and that the York River is primarily an estuary. It was found that the mean range of tide at West Point was 3.0 feet.

Comparative chemical analyses of the three main effluents of the pulp mill at West Point disclosed considerable difference in the amount of phenols, total solids, and biochemical oxygen demand of the three effluents.

In view of the fact that it is impossible for the oyster to feed during the time the shell is held closed, observations were made of the hours per day that oysters remained open in various localities. The oysters kept in the river were connected to recorders and their activities under natural conditions observed. It was found that the oysters of the upper York River were not open as many hours per day as the oysters of the lower part of the river, the averages being 15.28 hours per day for the upper York and 20.81 hours per day for the lower York.

Physiological experiments consisted of studies of the effects of pulp mill effluents on the respiration and feeding of oysters. Continuous records of the pumping activity of oysters show marked reductions in the amount of water pumped in concentrations of 1 part per thousand or stronger of liquor from the diffuser building. Studies employing the carmine cone and drop counting methods of measuring the ciliary activity of oysters showed that very dilute concentrations of the effluent from the diffuser building brought about depression in ciliary motion. In some instances concentrations as low as 1 part in 4,000 of the effluent in sea water reduced the rate of flow after exposure of 2 to 4 hours.

Using the drop counting method additional experiments were performed at Woods Hole, Mass. Employing the oysters and sea water of this region results were obtained showing reductions in rate of pumping when diffuser building liquor was added to the water supplied to the oysters. The reductions observed were similar to those found at Yorktown with the oysters and sea water of that region. It was also found from tests at Solomons Island, Md., and Beaufort, N. C., that the reductions in rate of flow of water through the oysters caused by the addition of pulp mill effluents were essentially the same as in the experiments carried on at Yorktown. These experiments were completed by the carmine cone technique.

Comparative studies of the physiological effects of the three main sewer outlets of the pulp and paper mill at West Point on oysters show that the most toxic is the effluent from the diffuser building; the next place is occupied by the paper mill effluent, while the discharge of the sludge pond is least toxic.

Tests with dried and ashed effluent of the diffuser building indicate that the material causing reduction in the rate of pumping by oysters is organic, for drying at low temperature and then redissolving in water materially decreases its toxicity. It was indicated by a series of experiments that aeration of the effluent for a month did not appreciably alter its toxicity. This is of particular interest since ponding of the effluent for slow oxidation is the plan of a new pulp mill being put into operation at Franklin, Va., in its endeavor to render the waste nontoxic to aquatic life.

The effects on oysters of fractions of the effluent and pure compounds known to occur in pulp mill wastes were tested to determine the active material of the effluent. Incomplete results indicate that the turpentine condensate resulting from the recovery of turpentine from the liquor is not particularly toxic to the oyster, nor was pure phenol under the experimental conditions employed. Observations on phenol salts, resins, and soaps are being continued.

Field and laboratory investigations have demonstrated that pulp mill effluent is toxic to oysters and that its discharge into the York River is primarily responsible for the decline of the oyster industry in this area.

Studies on the sporozoan parasite of the oyster.—Studies on the sporozoan parasite of the oyster which is very generally distributed in coastal regions from Maryland and Virginia to Louisiana were continued by Dr. H. F. Prytherch at Beaufort, N. C. Spores of this parasite were found in the tissues of the muscle, gills, and mantle, the number per oyster frequently amounting to several million. The mature spore (length 20μ diameter 11μ) contains a single vermiform sporozoite folded twice on itself and is the resting or final developmental stage in the oyster.

Under natural and laboratory conditions the hatching of the spores takes place in the intestine of the common mud crabs, *Panopeus herbsti* and *Eurypanopeus depressus* after these hosts have fed on infected oyster meats. After undergoing a cycle of development in the crustacean host, the parasite reaches an infective or gymnospore stage, which is released into the water and may be carried within the shell of the oyster by the feeding current.

Experiments with vitally stained gymnospores show that they attach to and penetrate the epithelium of the oyster gill by means of a pseudopod projected from the central cell. Later stages may be picked up by phagocytes and transported in the circulatory system to nearly all parts of the body. With the formation of heavy, double-walled sporocysts, the parasite has reached the characteristic resting or dissemination stage commonly found in *Ostrea virginica* and various other members of the same class of mollusks. Further details of the life history of this sporozoan will be published shortly in a scientific journal.

Studies of the effect of the parasite on adult oysters were conducted in the laboratory where heavy infections could be produced. In bulk experiments with several hundred oysters, losses of 66 to 73 percent resulted over a period of 3 months. Kymograph records of shell movement of heavily infected oysters showed abnormal and frequent contractions of the adductor muscle followed by loss of holding power and death of the mollusks. The injury to the oyster host may be due to a toxin given off by the developing sporozoites, particularly in the sensitive mantle tissue, or to actual physical obstruction of the circulation by the masses of enlarged, infected phagocytes found in the blood vessels of the gills and muscle.

Practical prevention of the infection of oysters by this parasite is possible by control of the primary hosts, the mud crabs. The crabs do not migrate and can easily be removed, before the beds are planted, by the use of dredges or scrapes equipped with fine mesh bags. The possibility of destroying the crabs by chemicals such as copper salts, chlorines, etc., is at present under investigation.

Investigations in Florida.—An experimental study of spawning and setting of oysters in Apalachicola Bay, Fla., was begun early in the spring by Dr. A. E. Hopkins. Because of the warm winter many oysters retained fully matured eggs or sperms in the gonads. Of samples taken early in March from St. Vincent Sound and Indian Lagoon, about half were mature. In the eastern portion of the bay, where the most extensive natural bars are located, only an occasional sexually mature individual was found. A month later, in early April, almost all specimens contained mature sex products. However, there was no indication of spawning until the end of April and the first of May, although for sometime previously the water temperature had been in general above 20° C. Spawning did not occur throughout the entire population at once but apparently involved only a small number of individuals at a time. A scattered set of seeds was obtained on bags of shells beginning at the end of May and continuing throughout the summer.

Tests were begun to determine the amount of meat present in oysters from different grounds with reference to the inside volume of the shells. The relative size of the shell cavity varies widely in oysters on different grounds. The volume of the shell cavity in relation to total volume is expressed as $\frac{100 \times \text{volume of cavity}}{\text{Total volume}}$ Total volume refers to the displacement of the entire oyster with shells intact but free from adhering organisms.

Each natural reef appears to be distinctive in the type of oysters produced. For some of the reefs in Apalachicola Bay values ranging from 30.82 percent to 41.83 percent were obtained. (Japanese oysters grown in the State of Washington average 52.64 percent inside cavity.) The volume of the cavity of the shell constitutes a limit to which the meats may develop, but it is important to note that the best meats do not necessarily come from the shells with the largest proportion of cavity.

Oyster meats were dried at 100° C., and the dry weight determined with reference to the volume of the shell cavities in which they lived. The following values, expressed as

$$\frac{100 \text{ x dry wt. in grams}}{\text{Volume of cavity in c. c.}}$$

represent the average of 20 to 25 specimens from each ground early in March before spawning had begun: St. Vincent Sound (transplants), 9.048; Indian Lagoon, 11.080; Cat Point, 4.337; Porters Bar, 10.863; Picoline Bar, 9.359; Platform Bar, 5.009; St. Vincent Bar, 4.666; Peanut Patch Bar, 3.745. Oysters from East St. Andrews Bay averaged 6.125 while Japanese oysters from Washington State averaged 11.732. Analyses of this type are being continued in conjunction with observations on hydrographical factors such as temperature, salinity, and pH of the water, abundance of plankton, degree of development of gonads, and spawning, in order to determine the conditions under which the best quality meats may be produced.

On account of unfavorable variations in salinity and turbidity of the sea water at the temporary laboratory at Indian Pass, near Apalachicola, Fla., headquarters for investigations were moved to the Pensacola Bay region. The Pensacola Quarantine Station of the Public Health Service was transferred to the Bureau of Fisheries for use as a laboratory. The main building has been equipped with running sea water and other necessities. The location is most favorable for oyster investigations, being within a short distance of the extensive oyster grounds of Florida, Alabama, Mississippi, and Louisiana, and having a supply of clear, clean sea water for laboratory investigations.

SPECIAL SURVEYS

Effect of dredging operations in Buzzards Bay.—At the request of the U. S. Engineer's Office, a special survey of oyster beds in Buzzards Bay was made by Dr. Loosanoff with the view of determining the condition of oysters and bottoms in the vicinity of the dredging operations performed by the War Department at the entrance to the Cape Cod Canal. Detailed information was supplied to the Engineer's Office as a result of this survey.

Survey of oyster bottoms in Shinnecock Bay, Long Island.—At the request of C. E. Dimon, secretary of the Board of Trustees of the town of Southampton, Long Island, N. Y., Dr. Loosanoff was detailed to study the conditions responsible for the disappearance of oysters.

It appears from the two surveys carried out in July and October in Shinnecock Bay, that the largest part of this once productive public oyster bottom is at present either much depleted or entirely barren. Studies of conditions existing in the bay failed to establish valid reasons why oysters could not be cultivated in that body of water. The presence of a large number of marine animals of various types ranging from the lowest invertebrates to fishes, and including many species closely related to oysters, also indicates that physical and chemical conditions in the bay are basically favorable. It seems, however, that the exceedingly dense growth of sea grass and hydroids on the bottom of the bay may be partly responsible for the lack of oysters in many parts of that body of water. Such a heavy growth covering the bottom undoubtedly prevents the setting of oyster larvae, and interferes with the circulation of water, thus depriving oysters of their food. It is probably significant that at the only station in the bay where oysters were found, little or no grass was brought up in dredges. A heavy growth of hydroids at that station was probably responsible for the poor growth of oysters. The abundance of starfish and drills is considered another factor responsible for the disappearance of oysters from the bay.

According to the town's regulations the oyster bottom of Shinnecock Bay is public property, no private ownership of the oyster grounds being permitted. Because of the almost complete disappearance of oysters, however, members of the community derive little benefit from the resource. The present regulations are therefore of sentimental rather than of practical value. The very fact that the oyster grounds are public property may be responsible for the disappearance of oysters. Oystermen who make their living from public beds take, as a rule, very little care of them. No regular shell planting is practiced, and no attempts are made to combat oyster enemies such as starfish and drills. As a result, these oyster bottoms which have been very prolific in past years are either entirely barren or show a marked decrease in yield. Because of lack of cultivation, oyster grounds are being gradually covered with debris and a dense growth of sea grass and hydroids, which make them unsuitable for oyster growing.

Considering the facts that Shinnecock Bay is at present virtually devoid of oysters and that the Board of Trustees has no funds to engage in oyster cultivation it is recommended that the bottom of the bay be leased to persons depending upon shellfisheries for a livelihood so that planting, cultivation, and protection of oysters may be resumed.

Pollution of water in Cherrystone Inlet, Va.—Upon the request of the Virginia Commission of Fisheries, investigations were carried out by Dr. Chipman to determine the cause of the high mortality of crabs and fish in Cherrystone Inlet last summer. It was found that the waters in question were polluted by cannery wastes. Determinations of the dissolved oxygen content and oxygen capacity of the water demonstrated the presence of a considerable amount of unstable organic matter in the water in the vicinity of the ditch leading from the cannery and extending into Cherrystone Inlet. From a 24-hour period of observation of the dissolved oxygen content of the water it was found that the dissolved oxygen in the early morning hours reached the extremely low level of only a few tenths of a part per million. Photosynthesis during the day brought about supersaturation of the water with oxygen in the late afternoon. The low oxygen area extended only a short distance into Cherrystone Inlet. On the basis of observations obtained from several trips to the area it was concluded that the high mortality of crabs and fish was a result of insufficient dissolved oxygen in the water, a condition brought about by the emptying of organic matter with high oxygen demand into the inlet by the cannery.

Investigations of the periodicity of fouling organisms.—At the request of the Bureau of Construction and Repairs, U. S. Navy Department, an analysis of the fouling organisms grown on experimental panels exposed at Cavite, Philippine Islands, and Guantanamo Bay, Cuba, was undertaken under the direction of Dr. Galtsoff. The work consisted in identifying the principal fouling groups and determining their abundance and the sequence of their appearance. The work was begun in September at the U. S. Fisheries Laboratory at Woods Hole and is being continued now by G. Robert Lunz, Jr., at the Charleston Museum, Charleston, S. C.

AQUICULTURAL INVESTIGATIONS

Dr. H. S. Davis, *in charge*

It is now generally conceded that proper and efficient utilization of the fish resources of our inland waters is to be achieved only through the adoption of a comprehensive plan of fish management adapted to the needs of each body of water. The rapid increase in the number of anglers coupled with the construction of thousands of miles of new highways has resulted in such a drain on the fish population that previous methods of more or less haphazard stocking have proved inadequate to cope with the situation.

The need for the development of management plans has served to focus attention on the lack of factual information on which such plans must be based. Although the artificial propagation and rearing of trout have been practiced on an ever increasing scale for many years, there is little information on the survival of hatchery fish after being liberated in natural waters. There can be no question that stocking with legal trout shortly before and during the open season has been a success. There are also a few instances where stocking with smaller fish is known to have resulted in a material improvement in fishing. In the great majority of cases, however, there is no evidence that artificial stocking has had a beneficial effect. On the other hand there is considerable evidence that, in many cases at least, stocking has had very little effect on the fish population and that even in heavily stocked waters wild trout frequently make up the bulk of the catch.

Although it is probable that artificial stocking has been more successful than is indicated by available information, the conclusion is inescapable that a large percentage of hatchery fish have been wasted and that the only hope for improvement lies in acquiring information that will enable us to avoid the pitfalls of the past. It is a striking commentary on fish management as practiced in this country that while hatchery operations and methods of transporting fish have been materially improved in recent years, the fate of the fish after stocking has received practically no attention. We are confronted with an anomalous situation in which a highly organized industry producing an extremely perishable product at great labor and expense is almost entirely oblivious to the fate of that product once it leaves the hatchery. Both fish culturists and anglers call for fish, and still more fish, without any attempt to determine whether increased production is the answer to the almost universal complaint that fishing is growing poorer each year.

In view of these facts, a large part of the activities of the aquicultural staff is devoted to acquiring information on the results of stocking and the survival and growth in natural waters of hatchery fish as compared with wild fish. In addition to field studies, investigations of hatchery problems have been continued and arrangements have been made to devote more attention to such problems in the future.

TROUT

Test streams.—The scientific work at the Pittsford (Vt.) station under the direction of R. F. Lord has centered around the "test waters" which are managed in cooperation with the State Fish and Game Service. During the past 2 years three streams and one lake—the maximum authorized by law—have been operated as test waters. Of these streams only Furnace Brook has been operated as a test stream for 3 consecutive years. The total catch of legal trout in this stream was 8,589 in 1935, 6,995 in 1936, and 6,385 in 1937. It is evident that in spite of heavy stocking the yearly catch is gradually decreasing, as is the average catch per fishing effort, which dropped from 7.2 trout in 1935 to 6.5 trout in 1937. On the other hand it is surprising to find, as pointed out in previous reports, that there has been only a slight decrease in the catch of rainbow trout, which have not been planted in the streams in recent years and are, consequently, entirely dependent on natural propagation. As a result of the much greater decrease in the catch of brook trout the proportion of rainbows in the total catch rose from 34 percent in 1935 to 38 percent in 1937.

During the past season a field census station was operated on Furnace Brook every week end to obtain accurate information on the marked trout taken by anglers. These fish were over 6 inches long when planted as yearlings in the fall of 1936. Although only 7 percent of the marked fish planted were reported by anglers, a creel check showed that approximately 50 percent of the marked fish taken were overlooked. This would indicate that of 5,200 legal fish planted in Furnace Brook during the fall of 1936 only about 14 percent appeared in the anglers' catches the following season.

There is, as yet, no information on the fate of the remaining 86 percent.

On an acreage basis it is estimated that the total production of trout in Furnace Brook was 45.55 pounds per acre in 1935, 37.45 pounds per acre in 1936, and 37.17 pounds per acre in 1937.

It is interesting and most encouraging from a fish management standpoint to find that, although the number of anglers was much greater early in the season than later, there was very close agreement throughout the season between the percentage of angling effort and the percentage of fish taken. In other words, the average catch per fishing effort was remarkably constant throughtout the season. This provides strong support for the view that where conditions are favorable for trout it should be possible to maintain good fishing up to the end of the season, even in heavily fished waters.

Growth and food studies on St. Mary's River.—St. Mary's River, a trout stream near Vesuvius, Va., in the George Washington National Forest, was stocked with marked brook trout above the falls (impassable) and with marked rainbow trout below the falls in 1935 and 1936. Owing to the poor growth of the fish, the stream was not opened to fishing in 1937 and thus afforded an opportunity for a study of the trout population by E. W. Surber and Dr. J. S. Gutsell. The fish were caught almost exclusively by angling and most of them were returned to the stream after examination.

It was found that brook trout planted in 1935 had grown to an average length of 5.6 inches in April, 6.2 inches in July, and 6.6 inches in November. Only a few rainbows planted in 1935 were caught but the 1936 planting was well represented. These fish averaged 6 inches long in April, 6.8 inches in July, and 7 inches in November.

An examination of the stomach contents of brook and rainbow trout caught in May 1936 showed that the number of terrestrial insects greatly exceeded that of aquatic forms. Of special interest was the evident importance of crayfish as a trout food and the presence of considerable quantities of algae in the stomachs of rainbow trout. Parasitic nematodes were found in nearly all stomachs of both species of trout. These worms were present in considerable numbers and may be responsible, in part at least, for the slow growth of trout in this stream.

Pisgah Forest project.—The experimental fish management project in the Pisgah National Forest (N. C.) has now been in operation for over a year in cooperation with the U. S. Forest Service. The project is under the supervision of Wm. M. Keil, of the Forest Service, while the biological work is being conducted by Thomas K. Chamberlain, of the Bureau of Fisheries staff.

A detailed survey of the streams under management has been completed and maps prepared showing the physical characteristics of stream channels and banks.

Collections of bottom samples at 51 stations have been regularly and systematically carried out. Five of the major watersheds of the forest are included in these studies, although most attention has been given to the Davidson River drainage, where monthly collections are made from 51 square feet of bottom. Although still far from complete for the purpose of calculating the maximum carrying capacities of the various streams, the results were used as criteria for setting up the initial stocking program.

Other investigations in this area include studies of the food of trout and other fish, collections of scales from brook, rainbow, and brown trout to be used in a comprehensive study of the growth of both wild and hatchery-reared trout in natural waters, and studies of the survival of trout after planting and their adjustment to the new environment, with special attention to the effect of winter conditions.

The Davidson River rearing station, constructed by the Forest Service, was operated very successfully. Sufficient trout of various ages and species were produced to carry out the stocking program as originally planned. Most of the fish were planted at 9 months of age and were as large as the average wild fish in their second and third years. While this growth rate cannot be expected to continue, these fish have at least been started in their new surroundings with strong, healthy bodies and a year's advantage in size. Specimens examined 2 to 3 months after planting were in excellent condition and compared favorably with wild fish in the same stream.

The Pisgah National Forest affords exceptional opportunities for fish management studies, since all streams can be opened or closed to fishing whenever desired and a complete check can be made of anglers' catches. The streams are patrolled regularly by Federal game wardens and there is little poaching.

Climatic and water conditions are also exceptionally favorable for management studies. The district has one of the heaviest rainfalls in the United States and participation is normally regular throughout the year. The comparatively short, mild winters allow a long growing season for fish and opportunities for studies of fish and fish food organisms that are not possible in more northern sections. Among the problems that are under investigation in this area is the extent to which both brook and rainbow trout of various ages and sizes migrate downstream when planted in the smaller and higher tributaries. The results of these studies will have an important bearing on the advisability of establishing so-called nursery streams that are closed to fishing on the assumption that the trout on reaching a certain size will descend to larger waters where they will be an important factor in maintaining the supply of legal trout.

Experiments are also under way to determine the stocking intensities of trout of various sizes that will produce most satisfactory results and the effect of various types of stream improvement on the production of fish and bottom food organisms. In several streams only marked trout of uniform size were planted so that it will be possible to get reliable data on the growth and survival of these fish.

California trout investigations.—The investigational program of this unit was continued under the direction of Dr. P. R. Needham, and good progress has resulted in spite of several changes in personnel and program. A. C. Taft resigned from the position of assistant aquatic biologist in January 1937, to become Chief of the Bureau of Fish Conservation of the California Division of Fish and Game. This position was not filled for the remainder of the fiscal year. As a consequence, the coastal stream steelhead investigations were turned over to the State Division of Fish and Game to be continued under the direction of that agency. Investigations at the Hot Creek Rearing Ponds Project were concluded June 30, and investigations on the survival rates of hatchery-planted trout by means of the Convict Creek experimental stream, operated in cooperation with the U. S. Forest Service, were substituted as a major project.

Twenty-three plants of brook, brown, and rainbow trout were made during the season of 1937 in the experimental stream. Various age groups were used, and plantings were made under varying predator conditions to determine survival rates over varying intervals of time. Several of the experiments were failures because of faults in the physical set-up, such as holes under dams and clogging of screens. The information obtained during this first year has pointed the way for future operations and the biological data have provided definite guides for stocking programs. From the successful experiments it was determined that hatchery-reared advanced fry suffer great losses in wild waters, but that hatchery fish from three to four inches long show a high survival. Brown trout did better than the other species with rainbow trout next in order of success in the experimental plants. Studies of condition factors showed that hatchery-reared fish lost weight after planting and a measure was determined for the optimum stocking intensity in relation to the food supply.

In one section a survival of 100 percent was obtained following a plant of rainbow trout based on the table developed by Dr. G. C. Embody. In another section, stocked with 1,000 advanced cutthroat fry, only 34 fish survived to the end of the season. The presence of 10 wild predatory trout was responsible for the heavy losses.

In future operation it is planned to divide the experimental stream into a smaller number of sections. Emphasis will be placed on planting experiments with rainbow and brown trout.

Boat catch records were again obtained from anglers fishing Convict Lake. The catch per unit of effort rose slightly from 0.21 fish per hour in 1935 to 0.27 fish per hour in 1936. A total of 365 trout were reported by 286 anglers in the 1936 season while 184 anglers took only 167 trout in 1935.

Of the trout caught in Convict Lake in 1936, over 49 percent were unmarked rainbows and approximately 48 percent were brown trout. Only seven marked rainbows from the plant of 2,014 (average length 5.67 inches) planted in July 1935, were reported caught by boat fishermen in 1936, while 349 of these fish were caught in the season of 1935. Therefore, in 2 seasons' fishing a total of only 356 trout, or approximately 18 percent, of the 2,014 planted in 1935 have been reported caught. However, such a low survival may prove to be more apparent than real, since fish planted in the lake can easily leave through either the inlet or outlet. Several reports were obtained of marked rainbow being caught as much as one-half mile below the lake.

Cooperative investigations with the U. S. Forest Service were continued in the national forests of California, Oregon, and Washington. A survey was completed and stocking policies were developed for the headwaters of the South Umpqua River above Tiller, Oreg., in the Umpqua National Forest. In addition, complete angling catch records were taken on Fish Lake by the Forest Service. Fish Lake, with an area of approximately 90 acres, lies at the very head of the Umpqua drainage. A total of 5,946 trout were reported caught, of which 5,878 were rainbow and the rest, eastern brook trout. The catch per angling hour was 4.18 fish. The total catch weighed 1,821 pounds which is a production of approximately 20 pounds of trout per acre of water area. The average length of the fish taken was about 9½ inches with an average weight of approximately 5 ounces. In 1935 and 1936 a total of 40,000 eastern brook trout were planted in Fish Lake, yet as noted above only 68 of this species were reported caught.

Through cooperative work in the Willamette National Forest in Oregon, a total of 174 lakes have been surveyed in the last 2 years and stocking policies recommended.

The U. S. Forest Service also financed the collection of catch records on Squaw Creek, a tributary of the Pit River in the Shasta National Forest. While no records were obtained for the month of May it is estimated that they are about 98 percent complete for the remainder of the season. A total of 2,497 rainbow and 7 brown trout were reported taken. The average catch was 7.4 fish per angler. Of rainbow trout taken, the 6- to 8-inch group formed 48.70 of the total and the 4- to 6-inch group 29.75 percent. Fish over 10 inches long made up only 5.3 percent of the rainbows caught. It is interesting to note that in the 4-year period from 1933 to 1936, 140,000 brown trout were planted in Squaw Creek. The fact that only 7 trout of this species showed up in the catch is strong evidence that conditions in Squaw Creek are not suited to brown trout and that the fish planted in this stream were wasted.

Introduction of Mexican trout.—In May 1937, Dr. P. R. Needham, accompanied by Fred Johnson of the U. S. Forest Service, made a trip to the Santo Domingo River in Baja California, Mexico, to secure living specimens of the southernmost coastal rainbow trout, *Salmo nelsoni*. The effort was highly successful and 50 fish were transported to the State hatchery at Forest Home in Southern California. These fish are to form the nucleus of a hatchery brood stock of this strain of trout. Efforts along this line are considered well worthwhile since it is hoped that these fish may be adapted to warmer water than other species of trout and that they also may prove to be nonmigratory. As soon as sufficient numbers are obtained, both laboratory and field experiments will be conducted to determine their true character and range of adaptability to varying stream conditions.

Nutrition studies.—Studies on trout nutrition have been continued at Cortland, N. Y., by Dr. C. M. McCay and A. V. Tunison. Two methods of attack upon the problems have been employed. The first attempts to improve current practices by the introduction of new feedstuffs that are available in large quantities and by improving the quality of the mixtures in current use. The second attempts to secure fundamental data in the fields of biochemistry, growth, and physiology in the interest of providing a sound basis of true science for guiding our changing practices. The study of disease at the Cortland Hatchery has been of minor importance since this involves special techniques that are not available. However, some attention has been given to diseases as they have arisen from time to time in the course of the other studies.

A better knowledge of the phenomena of growth whether of the entire body of the fish or of the component parts and their composition, is essential for a science of fish culture. For this reason four species of trout—rainbow, brook, lake and brown—have been under constant observation for 5 years. These four groups have been fed the same diet and kept under similar conditions in regard to the water supply. Growth curves for the four species under these conditions have been very similar. Increases in body weight have continued throughout this period but this growth rate has declined with succeeding years. This indicates that growth is determinate in fish although the cessation of increase in the size of the body is in a much later period of the life span than it is in higher mammals.

In the course of this long-time experiment certain species differences have been observed. All except the lake trout spawned at a normal age but this species did not spawn until September of 1937 when nearly 5 years of age. As the groups have become older there has been a tendency to develop ulcer disease and for individuals to die at about the spawning period in all groups except the lake trout. All of the brook trout have now died. The males of this group died before the females. The eggs from all groups have been consistently inferior and smaller than those from the same species held in ponds.

The question of the rate at which an animal should grow in order to develop the strongest body possible is one that is attracting increasing consideration in many fields of animal nutrition. No one desires to push the growth of an animal to the extent that he produces weaklings. One of the most difficult problems in the field is to determine what constitutes a weak animal in terms of the organs of the body and to detect weak organs that are unable to share in the growth of the body when that growth is unduly accelerated. For the above reason studies have been made of the rates of growth of the organs of the bodies of four trout species during the fingerling stage.

In this study the weights of the eyes, livers, hearts, and gastrointestinal tracts of trout were determined on April 16, July 9, and October 1. Part of the trout had been retarded in growth and part made to grow as rapidly as possible under our conditions. It has already been demonstrated by investigators working with other species that the organs of trout grow at unequal rates in comparison with the whole body. In cases of limited available foodstuffs certain organs, such as the eyes, are able to seize a disproportionate share compared to organs such as the heart. Thus, in retarded trout, the eyes grow more than the other organs and tend to represent a greater percent of the entire body weight. Organs such as the heart, liver, and the gastrointestinal tract represent about the same percent of the entire body weight whether the trout has been retarded in growth or not. In last analysis these organs and their composition probably determine whether or not the trout that are planted in the streams survive to greet the fisherman or die from their own inherent weaknesses. The tendency of the eyes to become a larger percent of the entire body weight may ultimately prove of some use as additional measurements of "condition factors."

As an additional part of the program to extend the science and to determine more about the relative hardiness of trout that are produced in hatcheries, the Cortland Station has continued its study of the chemical composition of trout of different ages. This work has been severely hampered by lack of both equipment and skilled assistants but progress is being made. As this phase of the work progresses it is hoped to include even the egg in its early development because here must lie some of the secrets of producing sound trout. Special attention is now being devoted to the exchange of nutrients between the sac and the fry in the period just after the eggs are hatched.

In the interest of improving the practical diets now used in the hatcheries special studies have been completed during the past year of such products as linseed meal, meats preserved in acid, various fish meals and seal meal. Linseed meal has been freed from its poison by steaming and pressure cooking. These processes provide a nontoxic meal that still retains the important property of binding water and liquids such as meat juices.

In the study of preserved meats it has been found that acids such as hydrochloric, phosphoric, and acetic, are satisfactory especially when their action is supplemented by that of molasses. After long storage of ground meats and molasses the meat tends to liquefy and to lose some of its value probably due to the loss of factor H. No evidence of toxicity has been discovered and the hydrolysis is only partial because there is little increase in amino nitrogen. A satisfactory method of keeping meats for long periods without spoilage, without deterioration in nutritive value and without loss of physical properties, has not been discovered thus far but progress is being made. The importance of such a development is evident since it would decrease the labor and the investment in refrigeration equipment as well as make it possible to purchase meat at periods of low prices.

Salmon carcass meal has proved somewhat more satisfactory in practical feeding than seal carcass meal although both can be used. White fish meal from which much of the bone has been excluded has been found of sufficient value to justify the additional cost of this special product.

The primary function of the Cortland station has been to develop a science of fish nutrition and to provide improved feeding practices for American hatcheries. Inevitably, however, diseases other than nutritional ones arise in the course of such investigations. These have been excluded when possible but some use has usually been made of epidemics to discover possible interrelationships with the nutrition.

During the spring of 1937, the yearling and adult brook trout developed ulcer disease. These were divided into groups and fed various vitamin concentrates and specific chemical compounds. Some of the products fed were vitamin C, extract of pine needles, potassium iodide, dried yeast, arsenious oxide, boric acid, borax, dinitrophenol, thallium acetate, and sulfanilamide. This heterogeneous list represents specific selections in a rational attack but failure resulted in every case. The last compound, sulfanilamide, was the only one that afforded any hope of usefulness that would justify further study.

During the past year efforts have been continued to develop better methods for chemical balance studies with trout. The aim of such studies is to measure the fractions of foods that are utilized after they are ingested by trout. In this work as in all projects involving chemical techniques, progress has been slow owing to the difficulties of the problem and to the deficiency in equipment and trained personnel.

At the Leetown, W. Va., station, an experiment was conducted with rainbow fingerlings, to test the value of certain commercial feeds in comparison with seal meal and salmon carcass meal manufactured by the Bureau. The dry foods were first fed at a 30 percent and later at a 40 percent level with beef liver. The fish fed salmon carcass meal rapidly outgrew those on other diets and at the end of the experiment were 42.4 percent heavier than those in the best of the other lots.

Selective breeding.—Selected lots of fingerlings were carried through the summer of 1937 at the Pittsford station and the best lots retained for breeding purposes. In the fall of 1937, 50 pairs of the best available 2-year fish were mated and the eggs segregated.

Owing to the necessity for economy in operation of the hatchery, it has not been possible to obtain maximum growth in the select lots but the effects of breeding are nevertheless manifest in the yield of eggs which averaged 1,370 per pound of fish instead of the usual rate of 1,000 eggs per pound for fish of the same size.

BASS

The field studies on smallmouth bass begun in 1936 were continued under the direction of E. W. Surber. These investigations are concerned with much the same problems in bass streams as are the trout studies in colder waters. Although, as already pointed out, there is a surprising lack of factual information necessary for the formulation of fish management plans for trout waters, the dearth of information concerning bass waters is even more marked. No systematic studies on the activities of bass in natural waters have been feasible throughout the year and there is practically no information on the normal productivity of bass waters. Although bass are now being propagated on an extensive scale throughout the country there is little evidence that fishing for either large or smallmouth bass has been appreciably improved by stocking. It is probable that natural propagation is more efficient than in the case of trout and that there may be less need for artificial aid. This, however, is a matter that can be determined only by comprehensive and systematic studies carried on continuously over a considerable period. It is for the purpose of securing such basic information that the investigations on bass streams were inaugurated and the results already obtained are of great practical value.

In addition to the two experimental sections previously established on the Shenandoah River near Berryville, Va., and on the South Branch of the Potomac River near Romney, W. Va., observations were made on sections of similar length in the Cacapon River near Largent, W. Va., and the North Fork of the Shenandoah River near Strasburg, Va. Stream conditions were entirely satisfactory for observations on the extent of natural propagation in the South Branch and Cacapon Rivers but in the Shenandoah and its North Fork visibility was much poorer.

Observations on spawning.—In the 1937 survey of the 3-mile section of the South Branch 205 smallmouth nests (68.5 per mile) were found on May 14 and 15, as compared with 142 nests found in this section during the 1936 survey. These nests were at an average depth of 33.2 inches and the average distance from shore was 9 feet. The eggs were counted in 10 nests and found to average 1,700 to each nest. Very few dead eggs were found.

In the Cacapon River, the average number of nests per mile was 13.75 and in the Shenandoah River there was an average of five nests per mile. Owing to the turbidity it is probable that some nests escaped observation. Fry counts made later along the same section indicated that the number of nests must have been considerably greater than observed. On the North Fork of the Shenandoah River an average of five nests per mile were observed in the experimental section.

In spite of these unfavorable conditions, a considerable number of older bass were taken for scale studies. In the South Branch of the Potomac River the average length of bass in their second year was 6.69 inches, in their third year 8.75 inches, in their fourth year 10.13 inches, in their fifth year 10.81 inches, in their sixth year 16.0 inches, and in their seventh year 17.0 inches. In other words, smallmouth bass in the South Branch did not attain the legal length of 10 inches until their fourth year and of the fish of this age more than 42 percent were under legal size.

In the Cacapon River the meager data available indicate that the situation is even less favorable. Of 24 smallmouth bass taken by angling on June 1, not a single fish was of legal size and the largest fish taken (9.75 inches) was in its fifth year. A 6-year fish was only 9.5 inches long.

On the other hand, bass in the North Fork of the Shenandoah River were found to make much more rapid growth. Here 2-year fish averaged 7.69 inches in length, 3-year fish 10.52 inches, and fish taken in their fourth year showed an average length of 12.13 inches. It is interesting to note that the North Fork is very nearly the size of the South Branch.

During 1937, progress was made toward placing field observations on a quantitative basis. Counts of bass in three sections of the South Branch of the Potomac River varying in length from 3 to 4.6 miles agreed very closely, showing, respectively, 105, 107, and 124 fish per mile. In contrast only 19 bass per mile were noted in the North Fork of the Shenandoah River.

It is of interest to note that in these rivers all of the bass appear to spawn at one time and there is no evidence of later spawning extending into the month of June. In the South Branch of the Potomac, where the extent of natural spawning is greatest, the fry disappear with extreme rapidity and there seems little doubt that the bass themselves are largely responsible for the losses.

Growth studies.—Fingerling bass in the South Branch of the Potomac attained an average length of 64 mm by mid-September while the trend in the growth of fingerlings in the Shenandoah River (no collections made after July 30) indicated that the bass in this stream again would have easily outstripped those from the South Branch had they maintained the growth rate shown by fish collected up to July 30, when the average length was 59.5 mm. In the Cacapon

River fingerling bass averaged 69 mm in length by September 1, and in the North Fork of the Shenandoah the average length on September 16, was 75 mm.

The 1937 season proved a poor one for the collection of fish and bottom organisms because of high water from frequent rains. As a result samples could not always be collected at regular intervals, and the number of fish caught was sometimes inadequate.

There seems little doubt from general observation that forage minnows are considerably more abundant in the Shenandoah River and its North Fork than in the South Branch and Cacapon Rivers, but to date the quantitative methods employed have not established this fact.

One of the most important results of the studies on the Shenandoah and South Branch of the Potomac Rivers during the past 2 years is the evidence that the latter stream is at present overstocked with bass. That this is the case is indicated by the large number of bass nests observed and the slow growth of young bass in the South Branch. In this stream smallmouth bass do not attain the legal length of 10 inches until their fourth year and over 42 percent do not reach this size until their fifth year. In contrast, bass in the North Fork of the Shenandoah, which is comparable in size with the South Branch, reach legal length in their third year and in their fourth year average two inches longer than bass of the same age in the South Branch.

The large number of nests observed in the South Branch also leads to some interesting speculations on the effect of stocking. As previously stated, an average of 68.5 nests per mile were observed in 1937 in the experimental section. Since the average number of eggs in each nest was approximately 1,700 and there were very few dead eggs it is evident that at least 115,000 fry per mile were produced. It is not probable that all the nests were seen, since observations were made only on two consecutive days, so that we may estimate the fry produced in this section of the river at over 125,000 per mile. There are approximately 75 miles of bass water in the South Branch and if we assume that an average of 100,000 fry per mile were produced in this area we find that it would require 7,500,000 fry to stock the South Branch at the same rate as was done by nature. Even if we reduce the estimate by 50 percent some 3,750,000 fry would be required, which would be a large order for any hatchery.

Food studies on fingerling smallmouth bass.—The stomach contents of 1,076 fingerlings collected at monthly intervals in test sections of the South Branch and Shenandoah Rivers have been examined. These collections permitted seasonal comparisons of the food of growing fingerlings from the time they rose from the nests until the end of the growing season. It was surprising to find that 10 percent of the Shenandoah River fry, averaging 10 mm long, had consumed fish. Many of these bass had not yet completely absorbed their yolk material. The chief items of food, however, were nymphs of the genus *Boetis* and midge larvae. As the bass increased in size, fish became more important in the diet, except in the South Branch where the data reflect a scarcity of forage minnows.

Bottom fauna studies.—A quantitative study of the bottom fauna in the Shenandoah and South Branch Rivers showed that the number and weight of organisms per square foot was much less in the pools than in the riffles in both streams, but in pools of the South Branch there was about twice as much food as in pools of the Shenandoah Rivers. The weight of organisms per square foot in the riffles was considerably greater in the Shenandoah than in the South Branch. Moreover, the former river has more extensive riffles in which bass can feed than has the latter.

Parasites in fingerling bass.—It was found that fingerling bass from both the South Branch and Shenandoah Rivers were infested with parasitic trematodes that were encysted in the liver. These parasites were much more numerous in fish from the South Branch than in those from the Shenandoah. Approximately 75 percent of fingerling bass from the former stream were parasitized as compared with about 12 percent from the latter. Bass from the South Branch also contained many more cysts, on the average, than those from the Shenandoah River. Considering the abundance of cysts in many instances, it is remarkable that there is no evidence that the parasites affected the growth since the average size of infested fish was very nearly the same as that of the uninfested.

Forage minnows in bass ponds.—Three ponds at the Leetown Station were stocked very heavily with blackhead minnows before the bass fry were introduced. Each pond when drained in the fall contained only a relatively small number of bass, although they were all of large size, averaging 6.5 inches in length. The obvious explanation of the disappearance of the bass fry is that they were eaten by the minnows although direct observations are lacking. In view of this possibility, it seems advisable to rear bass fry to a larger size before transferring them to ponds containing forage fish, or to defer the stocking of brood minnows until the fry have attained a length of three-fourths of an inch or more.

FISH DISEASES

Studies on fish diseases were continued by Dr. Frederic F. Fish at the pathological laboratory in Seattle, Wash. An investigation of furunculosis completed at Lake Madison, Mont., showed that a small percentage of loch leven trout were infected with the disease. Spawn-takers, however, reported the incidence of infected fish to be much lower than in 1934 and 1935. They also reported that the number of fish running into the traps showed a marked progressive decline during those years. It appears probable that furunculosis contributed materially to this decrease in the loch leven trout population in Lake Madison. If this supposition is correct cyclic increases and decreases in the numbers of these fish are to be expected in the future.

A program of disease control studies was instituted at the field laboratory recently constructed with the cooperation and financial assistance of the Division of Fish Culture at the Bureau's hatchery located at Quilcene, Wash. Both preventive and therapeutic measures for combatting the common hatchery diseases were investigated under controlled conditions. These experiments showed conclusively that fingerling trout can be subjected to routine preventive treatments at weekly intervals without incurring any increase in mortality.

In two series of experimental infections the common protozoan parasite *Cyclochaeta* was allowed to increase to epidemic proportions and various treatments in common use were then administered to determine their relative value. In most cases the treatments failed to produce the beneficial effects commonly ascribed to them. Common salt and the use of a malachite green solution at a concentration of 1,400,000 for 1 hour were more efficacious than other methods tried but even these were not effective in checking the disease. Unfortunately, all experiments had to be terminated early in October owing to the annual egg-taking activities at the station.

Considerable attention has been devoted to a myxosporidian parasite *Henneguya salminicola* Ward, which infests the pink and silver salmon of the Pacific coast. This parasite forms white cysts in the body muscles which, when abundant, give rise to the condition known locally as "tapioca." In some sections of Alaska a considerable percentage of the pink salmon may be infected with this parasite.

A disease caused by a myxosporidian parasite of the genus *Myxobolus* was found among bass fingerlings and brood fish at the Bureau's station at Miles City, Mont. It is claimed that the infection has been gradually increasing, its occurrence being estimated at 20 percent this year. The lesions appear as conspicuous lumps on the back and tail of infected fish. Since Myxosporidia require no intermediate host for completion of the life cycle it is feared the distribution of bass fingerlings from the Miles City station will result in widespread dissemination of the parasite. Studies on the parasite are being continued in the hope of developing some practical method of control.

The Disease Service maintained for assisting State, Federal, and private fish culturists in the solution of their disease problems has increased in popularity. Over 200 shipments of preserved specimens were sent to the Seattle laboratory for diagnosis and a large number of shipments were also received at the Washington laboratory.

INVESTIGATIONS IN INTERIOR WATERS

Dr. M. M. Ellis, *in charge*

POLLUTION STUDIES

Over 150 new localities have been investigated in the course of the stream pollution studies made by the staff of the Columbia, Mo., unit during the past year, and observations have been continued at some 70 old stations. The routine analyses and bioassays required to test and standardize the effluents and samples collected have occupied the time of five laboratory workers under the direction of an aquatic physiologist throughout the year. The combined data from these field and laboratory studies of pollution and polluting substances have been applied to fisheries problems in three ways. Using these data as a scientific background 43 major cases of stream pollution in North Carolina, South Carolina, Delaware, Virginia, Mississippi, Alabama, Louisiana, Texas, California, Oregon, Washington, Idaho, Montana, South Dakota, and New York, have been investigated this year by field parties from the Columbia, Mo., unit and reports have been prepared, or are in the process of preparation, for the guidance of officials and industries involved; over 200 answers to queries from State officials, manufacturers and others interested in particular pollution problems have been sent out; and understanding of the actions of industrial pollutants, particularly of dye wastes, pulp and rayon effluents, petroleum waters and mine waste has been materially advanced. The voluntary cooperation of many manufacturers in the practical application of these findings to definite pollution problems and in the following of recommendations for the elimination of pollution nuisances has been most gratifying.

This year's work has carried the pollution survey into several new States so that every State in the Union and all of the important river systems have now been included in the investigations. The field and laboratory work has been completed for the second part of the pollution bulletin.

The basic physiological studies of salmonids, bass, and catfish on which the applications of the pollution analyses and assays are made have been continued and extended to include the physiological reactions of fishes of these three groups to the minute quantities of the less abundant substances present in stream, lake, and impounded waters. Extensive experimental tests utilizing special apparatus developed for these physiological studies have been carried on throughout the year and are still in progress at the Columbia laboratories, and as a part of this work large series of catfish are being maintained under experimental conditions at Ft. Worth, Tex., by two members of the staff of this unit.

These physiological experiments have directed attention to the cumulative effects of prolonged exposures to very small quantities of substances which are apparently without immediate action on the fish. The tests with fluorides, for example, which are found in small quantities in many waters in the southwest, have shown that continuous exposure to even small quantities of these salts as found in some of the southwestern streams produces definite detrimental changes in the reproductive system and in the musculature of the fish, thereby impairing both the fertility of the fish and the quality of its flesh. Technical publications on these salts and several others will appear soon.

The field work correlated with these physiological studies of individual fish has involved the investigation of bog-fed streams, streams of glacial origin, mountain streams, and western impounded waters. Detailed surveys of the waters of Elephant Butte Reservoir, Lake Mead, and several of the smaller western impoundments were made during the summer in cooperation with a committee of the National Research Council and definite investigational programs were initiated at Elephant Butte and Lake Mead. This work was then continued in several western streams, including the Colorado, Columbia, and upper Missouri systems. Although not yet completed, practical applications of these studies have already appeared in connection with the stocking programs of various western streams on which impoundments are being built or are contemplated, and explanations have been obtained concerning the unproductiveness of certain reservoirs and streams in these regions. Twenty-five sets of analyses and assays have been made already for Federal and State officials to determine the suitability of waters from various springs, wells, and impoundments for fish or for fish hatchery purposes, in view of the physiological findings now available. Special equipment, not available heretofore, has been devised for the mobile field laboratories, and some of the physiological studies of the fish can now be made in the field.

MUSSEL PROPAGATION

The previous plantings of fresh-water mussels reported last year have been followed and extended. The observations to date show much better survival of the yellow sand shells than of the muckets. This may be due in part to the fact that the yellow sand shells grow much faster than the muckets and were more readily found. Even local mussel diggers who had not been apprised of the plants remarked on the increase in young yellow sand shells in the localities where plants had been made.

The program of plantings as previously outlined will be continued during the next 3 years, i. e., until a 5-year planting has been completed. At that time complete returns concerning the success of the restocking program will be available. Because an objection was raised by some of the manufacturers to the planting of yellow sand shells, fewer of that species were planted last year, but in view of the greater survival of yellow sand shells as noted above equal numbers of sand shells and muckets will be planted during the 1938 restocking.

ICHTHYOLOGICAL INVESTIGATIONS

Fishes of the Canal Zone and Panama.—Investigations on the Canal Zone and in Panama, begun in 1935, were continued in 1937 in cooperation with the Gorgas Memorial Laboratory and the Panama Canal by Dr. Samuel F. Hildebrand. A period of 3 months was spent in the field. During this time the locks at the Pacific end of the Canal were unwatered, and collections of fish were made (as in the locks at the Atlantic end in 1935). A study of the specimens and data is under way to determine to what extent the Panama Canal and the locks are used as passageways for fishes. Marine fishes have invaded the fresh water of the Canal to a surprising degree, and at least one species has crossed from the Atlantic to the Pacific.

A study of the feasibility of attempting further introductions of American food and game fishes in Gatun Lake (earlier attempts having failed) was made upon the request of the Panama Canal Government. It was decided that previous attempts to introduce fry had failed because of the great abundance of small native predatory fishes. It was therefore recommended that in the future the fish be reared to a length of six inches or more before liberation. Extreme caution must be exercised in the choice of species, because it is highly necessary to conserve the native mosquito-eating top minnows, important in the control of malaria.

General collections of fishes were made in various sections of Panama, both in fresh and salt water. The study of the fresh water material, which is nearly complete, has resulted in the discovery of several new species and has demonstrated that the fresh water fishes of the Atlantic and Pacific slopes have intermingled in the Canal to some extent and that limited hybridizing of very closely related species has taken place.

American Anchovies.—The study of the American anchovies undertaken by Dr. Hildebrand more than a year ago was continued as other duties permitted. Observations on Atlantic coast species of both North and South America are nearing completion. A few Pacific coast species, closely related to Atlantic species, also were studied.

The study has resulted in the discovery of several new species, in a better understanding of the relationships existing between the various species, and in a more logical division of genera.

Fishes of Tortugas, Fla.—Because of a desire expressed by the late Dr. William H. Longley shortly before his death, Dr. Hildebrand was requested by the President of the Carnegie Institution to complete a monograph on the fishes of Tortugas. Dr. Longley's studies had extended over many years, but his manuscript was unfinished at the time of his death.

General Systematic Studies.—Revisional studies of the genera of American fishes have been continued by Isaac Ginsburg. With the completion of a paper dealing with certain genera of the difficult family Gobiidae, the majority of the species of this family in American waters have been worked up on a sound scientific basis. In connection with his revisional studies Mr. Ginsburg gave his attention to the species problem, and published a preliminary paper on this question which is of general biological significance.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

Although the laboratory of the U. S. Fisheries station at Woods Hole was not open during the summer, a small number of outside investigators were accommodated for limited periods. As usual, the facilities were utilized in connection with the oyster investigations reported upon elsewhere. In addition, the following persons occupied and worked in the laboratory rooms: Dr. Hugh M. Smith, associate curator in zoology, U. S. National Museum, working on completion of report on fresh water fishes of Siam; Dr. Edwin Linton, University of Pennsylvania, helminth parasites of fishes; E. H. Barnes, biologist, Division of Fish and Game, Massachusetts State Department of Conservation, perfecting the methods of hatching and rearing lobsters; Dr. F. G. Hall, professor of zoology, Duke University, assisted by Dr. F. H. McCutchson, State College, Raleigh, N. C., and Dr. J. W. Wilson, Duke University, respiratory function of the blood of marine fishes. Lack of sufficient funds made it impossible to operate the laboratory on the same basis as in the years prior to 1932.

BEAUFORT, N. C.

Research.—Facilities for the study of marine fishery problems in the South Atlantic region were provided throughout the year by the Beaufort laboratory. The chief investigations conducted here by the Bureau's staff under the direction of Dr. H. F. Prytherch consisted of experiments and studies with reference to (1) the life history and control of a sporozoan parasite of the oyster, (2) the propagation of diamond-back terrapin, and (3) the utilization of marsh areas for mullet and oyster propagation.

Assistance was given to the following agencies, as indicated, on matters of importance to the fishery industries of the South Atlantic region: U. S. Engineer Department, advisability of deepening and maintaining Drum Inlet and Cape Lookout Inlet as an aid to the fishing industry in Core Sound, N. C.; U. S. Post Office Department, presentation of evidence pertaining to investigation of operations and claims of Florida oyster promoting concerns; Virginia Commissioner of Fisheries, studies of the reproductive condition of winter dredged crabs from Chesapeake Bay; North Carolina Department of Conservation and Development, practical procedure for continuation of oyster rehabilitation program; Duke University, construction of biological laboratory at Beaufort, N. C., for studies of marine life of this region; Union Carbide and Carbon Corporation, corrosion tests with stainless steel cable under marine conditions.

Laboratory facilities for marine research have been provided for 11 independent investigators from other institutions who were engaged in the following studies: Dr. H. V. Wilson, professor in the University of North Carolina, behavior of embryonic cells under controlled conditions; Dr. A. S. Pearse, Duke University, crustacean parasites and marine ecology; Dr. W. C. George, University of North Carolina, blood of Echinoderms and Annelids; Dr. Henry Vander Schalie, University of Michigan, the mollusca of the Beaufort area; Dr. H. H. Harkins, Fordham University, attachment of Cirripedia to submerged surfaces; Fred F. Ferguson, University of Virginia, morphology of marine Rhabdocoeles; W. Henry Leigh, University of Illinois, the parasites of marine fishes; Gordon H. Tucker, University of North Carolina, regeneration in certain of the lower invertebrates; J. Albert Fincher, University of North Carolina, cell behavior and embryology of sponges; John C. Ayers, Duke University, respiration of crustacea; George W. Wharton, Jr., Duke University, gregarine development in mud crabs.

Terrapin culture. The terrapin farm or hatchery operated at the U. S. Fisheries biological station at Beaufort is the largest in the world. It has produced more than 116,000 diamond-back terrapin since the artificial propagation of this species was undertaken in 1909. During the summer of 1937, 11,783 baby diamond-backs were hatched in the five concrete breeding pounds surrounding the station. This brood after being cared for under protected conditions for a period of approximately 9 months will be distributed throughout the South Atlantic region in cooperation with the various State conservation departments. Just prior to 1931 the brood stock was increased to 1,775 females and 440 males and since then the hatch of young terrapin has ranged from 10,060 per year to a record production of 13,245 in 1935. Capt. Charles Hatsel has been in immediate charge of this work since its inauguration.

Though breeding of diamond-back terrapin under seminatural conditions has been very successful, the general results indicate that each adult female has produced an average of only 6.5 young per year whereas twice this number should be expected according to previous experiments with small lots of animals. During the summer of 1937, experiments were conducted under the direction of Dr. Prytherch in which the brood stock was distributed in the breeding pounds in different concentrations and in varying percentages of each sex. It was found that the ratio of males to females, though varying from 1 to 2 to over 1 to 6, had no noticeable effect on egg production in the different pounds. The principal factor appears to be the degree of crowding of the brood stock as shown by the results from 3 similar pounds in which the hatch per female was 3.0, 6.2, and 9.3

with concentrations of 521, 482, and 310 adults per pound, respectively.

The best results were obtained when 310 adult terrapins were confined in a pen 60 feet square, at a ratio of 1 male to 6 females. This lot produced a total of 2,511 young. Two recent collections of wild stock, aggregating 342 invididuals, show that when the terrapin congregate at the natural breeding areas there is a sex ratio of approximately 1 to 6. Of further interest in this connection is the fact that terrapin previously reared from the egg to sexual maturity at the Beaufort station show a ratio of 1 male to 6.4 females.

Studies were also made in the early summer to determine whether a portion of the brood stock, consisting of rather old females, were "boarders" and incapable of egg production. Examination of several marked specimens from the original brood stock which has been in captivity since 1909, showed that each contained from 7 to 9 completely formed eggs and approximately 3 times this number of developing ova of various sizes. The mature eggs taken from these animals were placed in the sand beds used for incubation and showed a hatch of over 85 percent. These observations indicate that diamond-back terrapins are capable of producing a good supply of eggs and young until they are at least 40 years of age.

Utilization of marsh areas for oyster and mullet propagation.—In many parts of the world improved marsh areas and tidal flats are successfully used for fish and shellfish propagation. In cooperation with the Works Progress Administration a project was undertaken to construct a series of marsh ponds in the vicinity of the Beaufort laboratory to determine the value of such structures for increasing the production of oysters, mullet, and possibly other marine animals in the South Atlantic and Gulf region.

The construction of one large tidal pond, 2½ acres in extent, and several smaller ponds, 20 by 40 feet, is virtually completed and will be ready for experiments in 1938. A substantial dike 800 feet long separates the large pond from adjacent waters but permits a regular exchange of sea water by means of two tide gates. Each gate is supplied with 9 wire screens of 3 different mesh sizes to retain the young mullet that are to be placed in the pond in the early summer. The general plan is to rear the mullet to marketable size in this experimental pond from which they may be harvested at any time of the year, and to determine from its operation the most satisfactory and practical procedure for producing these fish in commercial quantities in larger ponds or controlled tidal bays. A considerable area of hard bottom, created in the pond by deepening and leveling operations, is suitable for growing oysters and clams and will be stocked with these shellfish. The shells of the oysters generally support a good growth of plant life which serves as a natural food supply for the mullet.

The series of smaller ponds which will be used primarily for oyster culture experiments have been excavated in a representative salt marsh area with adjustable gates for controlling the depth and flow of water. Ordinarily if seed oysters were planted at pond level so as to be exposed to air at times of low water they would produce inferior market stock because of attachment and crowding of subsequent generations. However, by maintaining a minimum depth of

1 foot or more of water in the ponds at all times this trouble can be eliminated as it is under similar natural conditions. In thus controlling the setting of oysters pond areas of protected bottom that are particularly suitable for growing and maturing these shellfish are created in the marsh. Such areas are greatly needed for the development of oyster culture in the South Atlantic region. Another advantage of this type of pond is the fact that it can be automatically drained at proper intervals for cleaning or harvesting purposes, and particularly for killing, by exposure to air, the boring sponge which is so destructive to oysters on submerged beds in this region. In operation of the ponds, a series of experiments and studies will be made as to the growth rate of oysters and their increase in volume in relation to density of planting, minimum depth of water maintained and the quantity of water supplied by tidal action.

APPROPRIATIONS

The biological investigations of the Division of Scientific Inquiry during the calendar year 1937 were conducted with funds provided by the annual appropriation, Inquiry Respecting Food Fishes, and with the aid of small balances, remaining in special funds made available for the fiscal year 1937. The appropriation for 1938 was $262,000 but required administrative savings of $30,000 reducing the actual working funds to $232,000. Travel funds appropriated separately for 1938 amounted to $27,000. Approximately one-half of each year's appropriation was spent in the calendar year.

The 1937 appropriation was about 4½ percent greater than for 1936 and the 1938 appropriation provided a further increase (of roughly 50 percent) in available funds. This increase served to offset the nonavailability of emergency and special funds which in 1937 amounted to $42,456 and to expand existing projects. A statement of funds for biological investigations is given below:

Project	1937	1938
Regular appropriations:		
Commercial fishery investigations	$113, 530	$133, 181
Oyster cultural investigations	19, 200	50, 579
Aquicultural investigations	33, 845	42, 500
Conserving fish by screens and ladders	1, 550	1, 500
Washington laboratory and administration	3, 875	4, 240
Traveling expenses		27, 000
Total	172, 000	259, 000
Allotment for maintenance and operation of vessels	26, 300	29, 000
Special funds:		
York River oyster pollution investigations	17, 456	
Shellfish pest control studies	25, 000	
Marine fouling studies		1, 500

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